FW: Draft CA Water Plan Review/Comment & Schedule

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Attachments: Chp 14. Surface Storage.pdf (117 KB) ; Vol3_Ch15_DrinkingWaterTre~1.pdf (281 KB) ; CAWaterPlan Vol3_Ch26_Sedi~1.pdf (407 KB) ; Vol3_Ch27_WatershedMgt_Pub~1.pdf (246 KB)

RE: Draft California Water Plan Update 2013

Staff representing the Los Angeles County Department of Public Works have reviewed and compiled comments for Chapters 14, 15, 26, and 27 of Volume 3,"30 Resource Management Strategies," of the Draft California Water Plan Update 2013. As instructed we have used the annotation features in Adobe to provide our comments.

Please contact me if you have any questions about the comments provided.

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Chapter 26. Sediment Management

> The management of sediment in river basins and waterways has been an important issue for water managers throughout history – from the ancient Egyptians managing sediment on floodplains to provide their crops with nutrients, to today's challenges of siltation in large reservoirs. The changing nature of sediment issues, due to increasing human populations (and the resulting changes in land use and increased water use), the increasing prevalence of man-made structures such as dams, weirs and barrages and recognition of the important role of sediment in the transport and fate of contaminants within river systems has meant that water managers today face many complex technical and environmental challenges in relation to sediment management.
>
> International Sediment Initiative, Technical Documents in Hydrology 2011

Sediment in California is a valuable resource when it is properly managed, which results in multiple water benefits, environmental health, economic stability, and coastal safety. Sediment definitions vary among the professional disciplines. Sediment, as reflected in this resource management strategy, is composed of natural materials and used contextually as follows:

1. Geology considers sediment to be the solid fragmented material such as silt, sand, gravel, chemical precipitates, and fossil fragments that have been transported and deposited by water, ice, or wind or that accumulates through chemical precipitation or secretion by organisms, and that forms layers on the Earth's surface. Sedimentary rocks consist of consolidated sediment.
2. The U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) regard sediment as material such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Sediments can come from anywhere and be just about anything. Organic and inorganic material alike can become bits of matter tiny enough to be picked up and carried along with a moving fluid. Organic sediments are mostly debris from trees, plants, grasses, animals, fish, and their waste products. Inorganic sediments are divided into two main groups; coarse-grained sediments and fine-grained sediments. Coarse-grained sediments are boulders, cobbles, gravel, and sand. Fine-grained sediments are silts and clays. Sediment deposits, like tree rings, can serve as a record of natural history.

A further important distinction is whether they are clean sediments or contaminated sediments, as this greatly affects the manner in which they can be used as beneficial material or if they must be isolated from their surrounding environment. For this resource management strategy, the term *sediment* will mean *clean sediment*, and if the *sediment is contaminated*, the term *contaminated sediment* will be used.

Debris management is also associated with sediment management. Debris may contain sediment, but it is not entirely composed of sediment. Likewise, debris is not trash. Debris consists of fragmented materials that are organic (trees, brush, and other vegetation) and are inorganic (soil, rocks, boulders, and other sediment) that is primarily moved by flood waters. Large woody material is key to sorting material and creating scours and pools. Pools provide an important habitat for juvenile fish, as well as refugia during flood events. Large woody debris also creates turbulences that clean spawning gravels. Debris basins are built in areas subject to debris flows to save lives and protect property. Trash consists of discarded human-made products (e.g., litter) that sometimes comingles with debris. Trash racks are typically placed on critical equipment, such as pump stations, to prevent mechanical failure caused by litter build-up during a flood.

Debris management is critical in flood management and includes the post disaster removal of materials — natural and human-made — generated by a flood and extreme weather events. Debris in these situations can range from boathouses to gravel bars to zoo enclosures.

While debris management is linked, this chapter focuses primarily on sediment management. Sediment management tools are essential for successful integrated water management as the presence or absence of sediment has a significant impact on water and its beneficial uses.

Sediment Management

Sediment, like fresh water, is limited in supply and is a valuable natural resource. Sediment management is critical for the entire watershed, beginning with the headwaters and continuing into the coastal shores and terminal lakes. However, from a human perspective, sediment has a dual nature; it is desirable in some quantities and locations and unwanted in others. Sediment contributes to many positive purposes and is also used for many positive purposes such as beach restoration and renewal of wetlands and other coastal habitats. Sediment is also needed to renew stream habitat. Spawning gravels need replenishment, and fine-grained sediment is needed to maintain, enhance, or restore good quality native riparian vegetation and wetlands. Flood deposits of fine-grained sediment into floodplains are the source of much of California's richest farmland. Sediment, particularly sediment adjacent to hot springs, has been considered for centuries to hold healing properties. Sediments can also be used for habitat restoration projects, beach nourishment, levee maintenance, and construction material.

The key to effective water-sediment management is to address excessive sediment in watersheds. Potential impacts of excessive sediment generally associated with fine-grained sediments are:

- Clouding water, degrading wildlife habitat, forming barriers to navigation, and reducing storage capacity in reservoirs for flood protection and water conservation.
  Increasing turbidity and suspended sediment concentrations and negatively affecting the ability of surface water to support recreation, drinking water, habitat, etc.
- Affecting sight-feeding predators' ability to capture prey.
- Clogging gills and filters of fish and aquatic invertebrates, covering and impairing fish spawning substrates, reducing survival of juvenile fish, reducing fishing success, and smothering bottom dwelling plants and animals.
- Physically altering streambed and lakebed habitat.

Other excess sediment issues sometimes include:

- Reducing the hydraulic capacity of stream and flood channels, causing an increase in flood crests and flood damage. Sediment can fill drainage channels, especially along roads, plug culverts and storm drainage systems, and increase the frequency and cost of maintenance.
- Decreasing the useful lifetime of a reservoir by reducing storage capacity. This loss in storage capacity affects the volume of stored water available for municipal supplies and the volume available for floodwater storage.

- Higher maintenance costs and potential problems associated with excess sediment in shipping channels, harbors, and drainage systems and disposing removed sediment. Excess sediment that accumulates in ports, marinas along the coast, working rivers and recreational lakes, affects boating and shipping activity and can lead to demands for dredging to restore or increase depths.

Toxic pollutants, including those from stormwater, may also be adsorbed onto sediments. Another key to effective water-sediment management is to address this contaminated sediment in watersheds. Contaminated sediment has a direct effect on aquatic life. Concentrated pollutants can greatly impair water quality if they are remobilized back into the environment. Potential contamination issues are:

- Direct effects on aquatic life.
- Toxic pollutants from stormwater may also be adsorbed onto sediments. Contaminates in sediments can bioaccumulate or magnify in the food chain and cause problems for aquatic plants, animals, and humans.
- Impaired water bodies.
- Nutrients such as nitrates, phosphorous, potassium, and toxic contaminants, such as trace metals and pesticides, when resent, are associated with fine-grained sediment. In some cases, suspended sediment particles increase bacterial growth, which can concentrate these nutrients.

Management of watershed sediment location and movement can also have positive and negative consequences, as well as large economic and ecological consequences. For example, excess sediment in shipping channels may cost ports millions of dollars in delayed or limited ship access, while in other locations insufficient sediment deposits could result in the loss of valuable coastal wetlands, beaches, recreation, and tourism, which are worth billions of dollars.

Sediment processes are important components of the coastal and riverine systems integral to environmental and economic vitality. Sediment management relies on knowledge about the context of the sediment system and forecasts about the long-range effects of management actions when making local project decisions. A major goal in sediment management is to stabilize and/or restore the watershed for sediment production meaning mimicking natural sediment production, not eliminating it, and thus provides the various ecological and beneficial uses. Watershed stability is determined by performing geomorphic assessments of the waterways within that watershed. Then, for the produced sediment, use this sediment most beneficially throughout the watershed.

Numerous factors including geology, climate, development and population, and the location of littoral cells affect sediment management issues. Littoral cells are self-contained sections, or a compartment, along the coast wherein sand enters (streams, cliff erosion) temporarily resides (beaches), and exits (submarine canyons, offshore shelf). These factors vary significantly throughout the state. For that reason, sediment is best managed on a watershed-littoral cell basis, taking into consideration the sediment source and needs from the top of the watershed to the coast where sediment will ultimately end. Adjacent littoral cells do not typically share sand whereas fine-grained sediments exhibit different behavior along the coast (e.g., turbidity plumes cross over cell boundaries). Regional sediment management recognizes sediment as a valuable resource and supports integrated approaches to achieve balanced and sustainable solutions for sediment related needs.

Management Framework

The Regional Water Quality Control Boards (RWQCB) provide regulatory oversight for transport of course-grained sediment to the coast and management of excessive watershed sediments. The USACE, EPA, State Lands Commission, and San Francisco Bay Conservation Development Commission also have authority for aspects of sediment management and dredging in their respective jurisdictions.

A stream that has excessive erosion, suspended sediments, and/or sedimentation may be determined by a RWQCB to be unable to support its designated beneficial uses and may be listed as impaired under the Section 303(d) of the Federal Clean Water Act. The RWQCBs are working to reduce excessive sediment within streams when it occurs within their regions through the use of total maximum daily load (TMDL) requirements. The *National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle* , shows that sediment is a major water quality problem in the nation's streams.

PLACEHOLDER Box 26-1 [explains beneficial uses from the Water Board's perspective]

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Partnerships have been formed throughout California to manage sediments better in a variety of ways. In San Francisco, the USACE, the EPA, the Regional Water Quality Control Boards, the San Francisco Bay Conservation and Development Commission (BCDC), and the State Lands Commission formed a partnership to address the disposal and beneficial reuse of sediment dredged from the San Francisco Bay. The Long-Term Management Strategy for the Placement of Dredged Sediment in the San Francisco Bay Region (LTMS) reduces in-bay aquatic disposal of sediments in favor of reusing that sediment beneficially in habitat restoration projects, levee maintenance, agricultural enhancement, and construction projects. LTMS emphasizes using sediment as a resource while simultaneously reducing impacts from aquatic disposal in the bay. This program coordinates and manages approximately 110 maintenance dredging projects, regulated by eight state and federal agencies under a common set of goals and policies. The LTMS policies and management practices also enable streamlining the permitting process, including coordinating programmatic consultations with the resource agencies, standardizing testing protocols, and increasing predictability for organizations with permits. There is also a quasi-LTMS process in the Delta.

On a statewide basis, the California Coastal Sediment Management Workgroup (CSMW) was established to develop regional approaches to restore coastal habitats, such as beaches and wetlands, that have been impacted by human-induced alterations to natural sediment transport and deposition through federal, State, and local cooperative efforts. CSMW is comprised of many State, federal, and local interests whose mission is to identify, study, and prioritize regional sediment management needs and opportunities along the coast and provide this information to resource managers and the public.

The CSMW was formed in response to concerns that shore protection and beach nourishment activities were being conducted on a site-specific basis, without regard to regional imbalances that could exacerbate the local problem. The consensus was that a regional approach to coastal sediment management is a key factor in developing strategies to conserve and restore California's coastal beaches and watersheds. The CSMW's main objectives include reducing shoreline erosion and coastal storm damages, restoring and protecting beaches and other coastal environments by reestablishing natural sediment supply from rivers, impoundments and other sources to the coast, and optimizing the use of sediment from ports, harbors, and other opportunistic sources.

The CSMW oversees the development of the California Coastal Sediment Management Plan (SMP) (http://www.dbw.ca.gov/csmw/smp.aspx). The SMP will identify and prioritize regional sediment management (RSM) needs and opportunities along the coast, provide this information to resource managers and the public, and streamline sediment management activities. A series of Coastal RSM Plans (strategies) are being developed for one or more individual littoral cells focusing on issues specific to each region. Tools, documents, and RSM strategies developed to date are available on the CSMW Web site (www.dbw.ca.gov/csmw).

Sediment Management and Flood Management

Sediment management is a key consideration in flood management. Sediment deposition in the channel or floodplain can decrease flood capacity/flood management. Sediment-starved channels can increase velocity, which can increase flooding.

When a river breaks its banks and floods, it leaves behind deposits of sediment. Sediment concerns consist of more than erosion. Overtopping can result in depositions in the channel or in the floodplain, which affect flood management. These depositions can reduce flood capacity. Rivers can also erode their banks and potentially erode levees or flood control structures. These gradually build up to create the floor of floodplains. Conversely, floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. These are accumulations of sand, gravel, silt, and/or clay, and are often important to aquifers because the water drawn from them is pre-filtered compared to the water in the river.

Geologically ancient floodplains are often represented in the landscape by fluvial terraces. Fluvial processes are the movement of sediment, organic matter, and erosion that deposits on a river bed, and the land forms this creates. Fluvial terraces are old floodplains that remain relatively high above the present floodplain and indicate former courses of a floodplain or stream.

When floodplains are separated from the water source, through levees or other means, the natural process of equilibrium, which elevates the land through sediment deposits, is interrupted. This alters the historic flooding and sediment distribution patterns. In some cases, sediments remain within the restrained channel, settling and reducing the capacity of the channel, and increasing the likelihood of flooding. In many cases, this is avoided by dredging the channel and then mechanically depositing the sediment in desirable locations.

Alluvial fans are another form of flood sediment deposit. Over geologic time, sediment, debris, and water emerge from the mountain front along different courses. Alluvial fans are found where these materials gather speed in narrow passages then emerge into less confined areas where they can change course. A number of factors contribute to the severity of these flows including the degree of steep grades to flatter grades. Sediment, debris, and water spill out in a fan shape, settling out and depositing on its way. The channels on these fans range from shallow to very deep (several meters) with a flow speed that can move boulders that are sometimes taller than a house. These conditions are found in California at mountain fronts, in intermountain basins, and at valley junctions. Alluvial fans are found where sediment loads are high, for example, in arid and semiarid mountain environments, wet and mechanically weak mountains, and environments that are near glaciers.

Historic Context

A combination of both natural and human-made impacts to California waterways has led to today's sediment management challenges and solutions. Historically and prior to California becoming a state, sediment flowed naturally from the mountains into streams, meadows, rivers, lakes, and the ocean. California Native Americans understood the seasonal and climate impacts of waterway flows and drought which impacted levels of sediment. This environment provided a wide variety of flora and fauna that was useful as food and tool manufacturing sources for native people (Theodratus 2009). As Europeans encountered the territories that became California, they altered this landscape by dredging passages of interior waterways for navigation, and captured a reliable water supply for their new settlements.

In addition to alterations to facilitate agrarian settlements, many of California's current sediment management issues also can be traced to historic gold dredge activities in the 1850s. California's Central Valley and Bay-Delta waterways experienced significant alteration caused by billions of cubic yards of sediment and debris sent downstream from hydraulic mining operations. Court action stopped these activities. However, impacts from these activities continue today. Ditches used for mining are still in use for agriculture and public water supply. The channel infilling that occurred in many of the gold bearing streams is still in evidence and many streams, such as the Feather and Yuba rivers, and these are still adjusting their watercourses 150 years later.

Some early reservoirs (Clementine, Englebright, Camp Far West) were initially built to capture the sediment. There are still millions of tons of mining debris remaining on the floodplain. The U.S. Geological Survey has measured the amount of sediment entering the San Francisco Bay from numerous tributary streams and determined the historic changes in sediment yield over the long term. Today, scientists have concluded that much of the hydraulic mining sediments have moved through the Delta and potentially through much of San Francisco Bay. However, multiple institutions, laws, and human settlement patterns created during this era remain, and, ironically, wetlands that were established as a result of the inundation are now undergoing erosion.

Beyond the Delta and Central Valley, impacts from historic and current road building and land management practices continue to contribute to existing problems. Landslides resulting from natural and human processes are a major producer of sediment.

Additional system alterations also occurred as dams and channels were built for both water supply and flood protection. More and more structures changed what had been the natural hydrology, which then altered system stability for sediments. As a result, the normal function of waterways has also been changed to produce sediment, move it through the watershed, with some settling occurring in low areas that are now typically used for farming or urbanization, and ultimately depositing it at the shoreline, replenishing the coastline or terminal lakes. In addition to sediment being trapped in flood control structures, peak velocities during storm events has also been reduced, limiting the ability of the stream to move coarse-grained sediment downstream to the coast.

Many ports and harbors were constructed in the 1940s and 1950s along the coastline without regard to the natural process of sand transport along the coast. This natural transport activity has been interrupted by the entrance channels to the harbors, such that the sand being transported down the coast is deposited instead within the entrance channels. This shoaling results in shallower depths and potentially hazardous conditions within the channel, necessitating the ongoing dredging of the channels to restore function and safety. Beneficial reuse of the dredged material is an opportunity for regional sediment management.

Due to the desire to work, live, and play along the coast, significant development along the shoreline has occurred without consideration of the impacts to such development by natural processes. As a result, much of the shoreline has been armored to reduce erosion at specific locations to protect specific structures. Such armoring has reduced the natural supply of sediment to the beaches from bluff erosion. This causes beaches to become more narrow and there is an associated loss of habitat and access from passive erosion and accelerating erosion of adjacent areas due to wave focusing.

Land use has also altered patterns of natural alluvial fans. As one example, much sediment in Los Angeles County is the result of the naturally erosive mountains. The San Gabriel Mountains are mostly undeveloped because they are within the Angeles National Forest. Other mountain ranges (Santa Monica, Verdugos, Puente Hills) also have large areas of undeveloped land. The basins and valleys below these mountains are large, relatively flat, alluvial plains. The depth of the sediment deposits indicates that a significant portion, and possibly the majority, of the sediment are from the adjacent mountains.

Many Los Angeles County residents/businesses moved into these flat alluvial plains. The original inhabitants, impacted by frequently fluctuating watercourse alignments caused by high amounts of sediment deposition, wanted more stable river/stream alignments for use and recharge. This situation led to the construction of dams, debris basins, channels, and spreading grounds in Los Angeles County to serve agricultural and urban areas. Farms and subdivisions were then located in naturally occurring sediment disposal areas Many of those inhabitants are unaware that they are sitting on still-active alluvial fans.

Management Approach

Understanding the cumulative impacts of all past, present, and proposed human activities in a watershed (and/or littoral cell) is important in predicting the impacts of sediment on surface waters. Sediment management in water bodies typically focuses on addressing three issues:

1. The type and source of sediment.
2. The systems transporting sediment.
3. The location where sediment deposits.

Management actions are tailored to the situation, depending on the location where the management actions will occur and whether the management actions involve a natural environment (rivers, streams, creeks, and floodplains) or a built environment (water control structures, flood levees, dams).

Source Management

Source management is preventing soil loss and adverse sediment flows from land use activities that may, without proper management, cause erosion and excessive sediment movement. Routine source management activities prevent or mitigate excessive sediment introduced into waterways due to recreational use, roads and trails, grazing, farming, forestry, and construction. Excessive flows affecting erosion and sedimentation may also result from land-based events such as extreme weather, fires, high water volumes, wind, and other factors.

Road construction and maintenance in or near streams can also be a source of sediment. Photo 26-1 is a picture of the Caltrans I-5 Antlers Bridge realignment project on Shasta Lake. The photo shows the dramatic erosion and sediment controls required for a massive cut and fill project that threatens surface waters (Central Valley Regional Water Quality Control Board 2011).

PLACEHOLDER Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Another transportation related source is off-highway vehicle (OHV) use. OHV is a popular form of recreation in California. State, federal, local agencies, and private entities provide recreational areas for this purpose. These OHV recreation areas are required to implement a range of sediment management and stormwater Best Management Practices (BMP) to protect water quality. Unfortunately, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted stormwater. With limited resources, maintaining and policing these areas can be a challenge.

Sedimentation can be a problem in the construction and operation of many mines. Increased potential for erosion and sedimentation at mines are related to mine construction and facility location. Tailings dams, waste rock and spent ore storage piles, leach facilities, or other earthen structures are all potential sources of sedimentation to streams. Road construction, logging, and the clearing of areas for buildings, mills, and process facilities can expose soils and increase the amount of surface runoff that reaches streams and other surface water bodies.

Agencies and Organizations Involved in Source Sediment Management

Many agencies and organizations contribute to sediment source management as land managers, land use planners, advisors, and regulators, and through training, technical and financial assistance, and promotion of good policy. An overview of some of those key entities and their activities are in Table 26-1.

PLACEHOLDER Table 26-1 Agency Roles and Activities in Sediment Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sediment Transport Management

Sediment, like water, flows downstream and supports both shorelines and habitats at the end of the line. Rivers and streams carry sediment in their flows. There is a range of different particle sizes in the flow. It is common for material of different sizes to move through all areas of the flow for given stream conditions. The sediment can also be in a variety of vertical locations within the flow, depending on the balance between the upwards speed on the particle (drag and lift forces), and the settling speed of the particle.

Sediment, primarily sand, also moves along the coastline as littoral drift. This "river of sand" is driven by wind and waves interacting with the shoreline and its orientation. Sand enters the littoral cell from streams and rivers, moves downcoast picking up additional contributions from eroding bluffs, and leaves the littoral cell when it reaches a submarine canyon. Some sand is also lost to the offshore during large storm events. The sand resides temporarily along the coast as beaches, and fluctuations in the supply/loss of sand to the system will affect beach widths.

PLACEHOLDER Box 26-2 Definitions

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Sediment transport management is the process of introducing or leveraging natural functions that create optimal sediment transport. This involves managing the speed and flow of the sediment conveyance and the natural or built structures to achieve a properly distributed balance of sediment types in the habitat. Properly managed transport of sediments will result in the optimal sediment deposition.

For example, sand bypass structures in flood control channels are starting to be used. Such structures placed into flood channels allow the coarse-grained sediments to be diverted to a settling pond where they can be excavated and used for construction, while the fine-grained sediments are diverted to a wetland where they add to the size of the wetland. More information on this method can be seen at http://www.ocwatersheds.com/Documents/wma/LaderaRanch_HNouri.pdf and http://www.ocwatersheds.com/Documents/wma/Integrated_Mgmt_of_Stormwater_Sediment_and_Pollutants_in_Ladera_Ranch.pdf.

Sand transport management along the coast includes dredging harbor entrance channels that have become clogged with the migrating sands, and transporting the dredged materials to some other location. In some areas, sand traps have been constructed to facilitate such transport prior to the sands entering the harbors. Elsewhere along the coast, retention structures (e.g., groins) have been constructed to slow down the alongshore transport, maintaining beach widths for longer periods of time. If the area upcoast of the groins is not properly filled with sand, beaches downcoast of the groins can experience accelerated erosion.

Sediment Deposition Management

The goal of sediment deposition management is to achieve optimum benefits from sediment deposits and mitigate negative impacts. As noted previously, properly distributed sediment has numerous beneficial outcomes such as:

- Fine-grained sediments supporting existing habitat and adapting to sea level rise.
- Gravel remaining in rivers and streambeds for habitat and riverbed stability.
- Sand sustaining beaches both for recreation and habitat.
- Fine silts and clays introducing nutrient rich materials and nutrient cycling.
- Deposits creating buffers, particularly offshore, that reduce climate change and storm surge impacts. Coastal areas that benefit from sediment can also include offshore mudbelts.

Deposition management also includes techniques to prevent and mitigate the negative aspects of excessive sediment including:

- Siltation creating an impact the capacity of floodways, reservoirs, and water supply systems including dams.
- Siltation creating unsafe shipping and transportation channels and creating an impact on other commercial and recreational navigation.
- Siltation inundating wetlands.
- Deposition filling pools and embed riffles, which reduces stream habitat.

The USACE maintains the primary federal permitting and operational responsibility over waterway and navigational dredging, flood control, and the operation of many dams. The EPA oversees USACE's implementation of its Clean Water Act and Marine Protection, Research, and Sanctuaries Act (MPRSA) responsibilities, as well as establishing water quality criteria and implementing certain TMDLs. Additionally, the U.S. Bureau of Reclamation maintains a significant federal role in maintenance, construction, and even deconstruction of dams.

The California Coastal Commission, Department of Water Resources, the State Lands Commission, State Water Resources Control Boards, and BCDC serve as State counterparts. Additional federal and State resource agencies are responsible for fisheries and recreation.

Dredging and Sediment Extraction

Dredging is an excavation activity or operation usually carried out, at least partially underwater, in shallow water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable.

Other forms of sediment extraction can be completed by various methods including scraper, dragline, bulldozer, front-end loader, shovel, and sluicing. Sluicing is a sediment removal method that employs water flow to remove smaller particle sediment (i.e., sands and silts) to remove sediment accumulated in reservoirs. Sluicing is one of the two methods the Los Angeles County Flood Control District has used since the 1930s to remove sediment from its reservoirs.

Extraction methods are often used to maintain the capacity of flood and water supply infrastructure and mine sediment, sand, and gravel for multiple purposes such as commercial construction, levee stabilization, and environmental restoration. Determining how the extracted sediment will be managed involves a variety of factors including environmental acceptability, and technical and economic feasibility.

Dredging is a critical sediment deposition management activity supporting commercial shipping, homeland security, fishing, recreation, and environmental restoration. Detailed descriptions of dredging equipment and dredging processes are available in Engineer Manual (EM) 1110-2-5025 (U.S. Army Corps of Engineers 1983; Houston 1970; Turner 1984).

In San Francisco Bay alone, dredging facilitates a substantial maritime-related economy of more than $7.5 billion annually. By necessity, maritime facilities are located around the margins of a bay system that averages less than 20 feet deep, while modern, deep-draft ships often draw 35 to 50 feet of water or more. In order to sustain this region's diverse navigation-related commercial and recreational activities, extensive dredging — in the range of 2 to 4 million cubic yards (mcy) per year — is necessary to maintain adequate navigation channels and berthing areas. Effective management of the large volumes of dredged material generated throughout this estuary is both a substantial challenge and an opportunity for beneficial reuse. Both are addressed by the Long Term Management Strategy for Dredging (see http://www.bcdc.ca.gov/pdf/Dredging/EIS_EIR/chpt3.pdf) and the interagency Dredged Material Management Office. Navigational dredging in Southern California is similarly managed to encourage beneficial reuse wherever possible under the Los Angeles Basin Contaminated Sediment Management Strategy's Master Plan and the interagency Dredged Materials Management Team.

There are some known issues related to dredging and other forms of sediment extraction:

- Dredging and sediment extraction can directly impact water quality, habitat quality, and contaminant distribution. Operations may reduce water quality by introducing turbidity, suspended solids, and other variables that affect the properties of the water such as light transmittance, dissolved oxygen, nutrients, salinity, temperature, pH, and concentrations of trace metals and organic contaminants if they are present in the sediments (see http://www.spn.usace.army.mil/ltms/chapter3.pdf).
- Depending on the location of the dredging, deepening navigation channels can increase saltwater intrusion since saline water is heavier than freshwater, potentially causing an impact to freshwater supplies and fisheries (e.g., deepening of the Sacramento and Stockton deep water ship channels in the Delta). Dredging can also increase saltwater intrusion into groundwater aquifers (e.g., the Merritt Sand/Posey formation aquifer in the Oakland Harbor area), with consequent degradation of groundwater quality in shallow aquifers.
- Sediment removal operations may also reintroduce contaminants into the water system by re-suspending pollutants. Metal and organic chemical contamination is widespread in urban shipping channels due to river runoff and municipal/industrial discharges. Chemical reactions that occur during removal may also change the form of the contaminant. These chemical reactions are determined by complex interactions of environmental factors, and may either enhance or decrease bioavailability, particularly those of metals. At the same time, dredging can aid in overall reduction of pollutants in a water body when contaminated sediments are removed from the system or sequestered in habitat restoration projects.

Many things have been done to address these existing issues. There are pre-dredging and real-time monitoring programs that have been developed to test the quality of sediments to be dredged, and there are alternative disposal sites where different quality sediments can be taken. Time windows for when some dredging can occur have been established to accommodate certain ecological cycles. Upland sediment disposal sites can be designed to mitigate for many contaminants, and extremely contaminated sites can be capped in-place underwater. Evaluation of dredged material for ocean disposal under the Marine Protection, Research, and Sanctuaries Act (MPRSA) relies largely on biological (bioassay) tests. The ocean testing manual, Evaluation of Dredged Material Proposed for Ocean Disposal - Testing Manual), commonly referred to as the Green Book, provides national guidance for determining the suitability of dredged material for ocean and near-coast disposal. Evaluation of dredged material for inland disposal under the Clean Water Act (CWA) relies on the use of physical, chemical, and/or biological tests to determine acceptability of material to be disposed. The inland testing manual, *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. - Testing Manual*, provides national guidance on best available methods.

Beneficial reuse of dredged and extracted sediments can solve what can otherwise be a dilemma of how to dispose of dredged and extracted sediments as a waste by repurposing it in a variety of ways. These can be used to raise subsided lands to allow restoration as an agricultural supplement and to support levees. When this occurs, the economics of disposal may be altered. In particular, the initial cost to the dredger for sediment removal and placement may be increased. For example, reusing the sediment may require different equipment, the transportation distance to the reuse site may be greater than to the traditional disposal site, and the amount of time needed to complete the dredging work may be extended. In addition, sediment is a public trust asset and thus it is subject to State mineral extraction fees and other restrictions. Because public trust lands are held in trust for all citizens of California, they must be used to serve statewide, as opposed to purely local, purposes.

Dam Retrofit and Removal

Dams are an important part of California's water and flood management and will remain so for the foreseeable future. Sediment deposits naturally behind dams and reservoir sediment management includes a range of options including sluicing of sediment, dredging, redesign, retrofit, and removal.

Dam retrofit is an option for deposition management. The Natural Heritage Institute (NHI), a non-governmental and non-profit organization, has been a pioneer in this area. They are investigating the feasibility of re-operating some dams in order to restore a substantial measure of the formerly productive floodplains, wetlands, deltas, and estuaries located downstream in ways that do not significantly reduce — and can sometimes even enhance — the irrigation, power generation, and flood control benefits for which the dams were constructed.

Dam removal is sometimes a result of sediment management, or it creates a need for sediment management. As noted earlier, sediments trapped behind dams or in reservoirs may require periodic sediment removal to maintain function and capacity. However this is sometimes extremely challenging due to the facility's location and the lack of disposal or beneficial reuse opportunities at nearby locations. In recent years, there has been increased interest in dam removal for sediment-related reasons, such as the loss of capacity of the facility to hold water due to accumulated sediment. In other cases, the reasons may be unrelated, such as a need to upgrade hydrogenation or improve a stream fishery. Analysis of dam removal proposals requires significant discussion of sediment deposition management. Management of sediments behind such dams has been an important element of negotiations related to dam decommissioning.

Regional Sediment Management

Regional Sediment Management (RSM) refers to the practice where sediment is managed over an entire region. Managing sediment to benefit a region potentially saves money, allows use of natural processes to solve engineering problems, and improves the environment. RSM as a management method:

- Includes the entire environment from the watershed to the sea.
- Accounts for the effect of human activities on sediment erosion as well as its transport in streams, lakes, bays, estuaries, and oceans.
- Protects and enhances the nation's natural resources while balancing national security and economic needs.

RSM is an approach for managing projects involving sediment that incorporates many of the principles of integrated watershed resources management, applying them primarily in the context of coastal watersheds. While the initial emphasis of RSM was on sand in coastal systems, the concept has been extended to riverine systems and finer materials to completely address sources and processes important to sediment management. It also supports many of the recommendations identified by interagency working groups for improving dredged material management. Examining RSM implementation through demonstration efforts can provide lessons not only for improved business practices, techniques, and tools necessary for managing resources at regional scales, but also on roles and relationships that are important to integrated water resources management.

This is a growing concept nationwide which also has economic benefits. The USACE has a primer on Regional Sediment Management at http://www.spur.org/files/u35/rsmprimer.pdf.

More information about RSM can be found in the American Society of Civil Engineers written Policy Statement 522, on Regional Sediment Management at http://www.asce.org/Content.aspx?id=8638.

Connections to Other Resource Management Strategies

Many other resource management strategies in *California Water Plan Update 2013* share a connection with sediment management. More information on each of these resource management strategies can be found in these chapters under Volume 3, *Resource Management Strategies, California Water Plan Update 2013.*

- "Agricultural Lands Stewardship," Chapter 21. Agricultural land stewardship directly links to management of erosion and soils protection. Proper management in both private and public land ownership prevents disruptive development patterns and supports sediment aware farming and ranching practices.
- Conveyance. Depending on design, conveyance facilities can either trap, scour, or result in other unnatural distribution of sediments. Sediment overload can significantly reduce system capacity.
- "Ecosystem Restoration," Chapter 22. Native riparian, aquatic, animal, and plant communities are dependent on effective sediment management. These ecosystems are dynamic and are highly productive biological communities given their proximity to water and the presence of fertile soils and nutrients. Many opportunities for improvement in both sediment management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. Sediment management projects that result in protected and restored ecosystems will likely create increased effectiveness, sustainability, and public support.
- "Flood Management," Chapter 4. Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of the floodplain, the depth and composition of soils, and the type and density of vegetation. Sediment transport dynamics can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying capacity of natural channels through increased sedimentation. Sediment is also a major component of alluvial fan and debris-flow flooding.
- "Forest Management," Chapter 23. Forestation practices can influence sediment transport from upland streams. Wildfires can reduce surface water infiltration, which can cause additional erosion and debris flooding.

- "Land Use Planning and Management," Chapter 24. The way in which land is used — the type of land use, transportation, and level of use — has a direct relationship to sediment management. One of the most effective ways to reduce unnatural sediment loads is through land use planning that is fully abreast and reflective of applicable sediment and hydrology practices. This includes site design to reduce the introduction of unnatural loads of sediment into waterways.
- "Outreach and Engagement," Chapter 29. Outreach is needed to educate the public regularly on sediment management concerns. Outreach is also needed to educate the public on the natural beneficial functions of sediment.
- "Pollution Prevention," Chapter 18. Well-designed pollution prevention efforts improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion, and sedimentation of streams.
- "Municipal Recycled Water," Chapter 12. Soil structure can be altered by the composition of water that interacts with it, particularly sodium-loaded soil that may be found in many soils that have been irrigated with some recycled waters. Soil organic matter increases both the water-holding capacity of mineral soils considerably and the cation-exchange capacity. In soil science, cation-exchange capacity (CEC) is the number of positive charges that a soil can contain. It is usually described as the amount of equivalents necessary to fill the soil capacity. CEC is used as a measure of fertility, nutrient retention capacity, and the capacity to protect groundwater from cation contamination. Some studies about infiltration rates between local well water (slightly calcic) and recycled water used for irrigation on a silty clay loam have found significant differences and reduced infiltration for the soils subject to the recycled water.
- "Urban Stormwater Runoff Management," Chapter 20. Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways and the timing and extent of sediment introduction into the system. The impervious surfaces increase runoff volumes and velocities, resulting in stream bank erosion and potential unnatural sediment distribution downstream. Watershed approaches to urban runoff management attempt to manage sediments to mitigate negative impacts and support beneficial uses in a manner that mimics the natural hydrologic cycle.
- Surface Storage. Similar to conveyance, sediments may be trapped behind infrastructure or otherwise unnaturally distributed. This results in a loss of system capacity.
- "Water and Culture," Chapter 30. Sediment is used in traditional ceremonies and considered to contain healing, and in some cultures, it has spiritual properties. Mud structures are important to native peoples and for some, mud has ties to the creation story. See *Tribal Water Stories* at http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf.
- "Water-Dependent Recreation," Chapter 31. Water and land-based recreational activities can contribute to unnatural erosion and sediment production. Conversely, high sediment loads can negatively impact recreation, particularly boating, fishing, and swimming. Adequate supply of sand and gravel sediments is essential for many beach recreational activities.
- "Watershed Management," Chapter 27. Watersheds are an appropriate organizing unit for sediment management. Restoring, sustaining, and enhancing watershed functions are goals of sediment management in the context of integrated watershed management.

Potential Benefits

The ultimate benefits of sediment management relate to preventing the negative results of too little or too much sediment and repurposing sediment for beneficial uses. As noted above, benefits associated with reducing impacts just to navigation and commerce may achieve cost savings of millions. A similar statement can be made about the management of sediment that accumulates at reservoirs and debris basins and is prevented from flooding communities downstream.

Source Sediment Management

An average of 1.3 billion tons of soil per year are lost from agricultural lands in just the U.S. due to erosion (McCauley and Jones 2005) (http://landresources.montana.edu/SWM/PDF/Final_proof_SW3.pdf). Considering that soil formation rates are estimated to be only 10–25% of these erosion rates (Jenny 1980), loss and movement of soil by erosion is a major challenge for today's farmers and land managers. Soil erosion over decades can have detrimental effects on productivity and soil quality because the majority of soil nutrients and soil organic matter (SOM) are stored in the topsoil, which is the soil layer most affected by erosion. For these reasons and more, sediment management for soil sustainability has numerous multiple benefits far exceeding the scope of the California Water Plan.

In the case of urban land management, use of low-impact development and other sediment management practices can reduce negative impacts of stormwater runoff, by maintaining the natural production of sediment and improving permeability of drainage areas. Land use goals for sediment may also improve flood management. By improving the flood system hydrology, sediment management results in improved safety and environmental and economic outcomes.

Coastal Sediment Management

Sediment in the coastal waterways can furnish material needed to replenish the beaches and marshes along the coastal areas. If the sediment is removed from navigation channels or harbors, the extracted material can be used for beach or marsh nourishment, construction purposes such as highway sub-base material, and flood control levees.

Widening the shoreline, either via beach nourishment or marsh restoration, improves storm surge and flood protection. The dollar value of this improved protection is nearly incalculable, not just for those who own coastal structures, but for the extraordinary number of infrastructure improvements that support the state, including power generation, major transportation assets, water systems, and the dollar value of the recreation and tourism industries that are large part of the state's economy. Restoring eroded coastlines also improves habitat for coastal biota and improves access safety to the shorelines.

Fisheries

In terms of water management, natural amounts of coarse-grained sediment (sand and gravel) in the stream and river system has many beneficial uses. It can serve in the inland waterways as a substrate for fish spawning areas. Enhancing the sustainability of the fishery benefits not only the state's fishing industry, but is also a water supply benefit as a declining fishery may lead to reductions of water exports or use of some water rights.

Beneficial Uses for Extracted Sediment

Extracted sediment is a manageable, valuable soil resource with beneficial uses of such importance that it should be incorporated into project plans and goals at the project's inception to the maximum extent possible. For example, extracted sediment can benefit:

- Habitat restoration/enhancement (wetland, source, island, and aquatic sites including use by fish, wildlife, waterfowl, and other birds).
- Beach nourishment.
- Aquaculture.
- Parks and recreation (commercial and noncommercial).
- Agriculture, forestry, and horticulture.
- Strip mine reclamation and landfill cover for solid waste management.
- Shoreline stabilization and erosion control (fills, artificial reefs, submerged berms.).
- Construction and industrial use(including port development, airports, urban, and residential.
- Material transfer for fill, dikes, levees, parking lots, and roads.
- Multiple purposes (i.e., combinations of the above).
- Coastal Access.
- Storm Surge Protection.

The applicability of uses is subject to the demand for materials. An issue or barrier might be matching disposal to uses. A detailed discussion about various beneficial uses for extracted material is at http://water.epa.gov/type/oceb/ndt/beneficial_use.cfm and other related sources.

System Capacity and Materials Use

There are multiple benefits of managing the sediment that accumulates at reservoirs and debris basins. If sediment that accumulates in reservoirs is not removed, storage capacity is reduced. As an example, flood control reservoirs which have a water conservation purpose (and most of them do), water captured in the reservoirs maybe used to recharge local groundwater aquifers. If sediment is not removed or is passed through, then the storage capacity for water or hydropower is reduced. If sediment is not removed from reservoirs and debris basins, the ability to provide flood risk management, water supply, or hydropower is diminished.

Special Situations

The battle to maintain Lake Tahoe as a pristine and visual jewel is an unusual sediment case study. The sediment of concern is very fine-grained sediment (less than 20 microns) that affects the clarity and people's aesthetic enjoyment of Lake Tahoe. In this case, the problem may be unique and the extensive costs of basin-wide improvements would not translate to other situations. Even so, there have been many new and innovative best practices for sediment management in the basin and these can translate to other programs. Additionally the benefits of the investment have been equally evaluated and are considered to be of national interest.

Potential Costs

[PLACEHOLDER FROM WATER BOARDS - Include Lake Tahoe MS information on investments.]

Many agencies and organizations engage in sediment management activities. The cost of implementing sediment management to achieve water benefits varies widely depending on the sector and purpose of the management. When looking at the overall costs of sediment management, managers should consider and quantify the beneficial uses of the sediment and the ecosystem services, flood protection, storm surge protection, and water quality improvements associated with the benefits as a balance in comparison to the up-front financial investments. While the financial investment is often a one-time cost, the benefits are regularly long term, such as creating a wetland that provides habitat and water quality improvements in perpetuity.

A few sample investments in sediment management include:

Natural Resources Conservation Service (NRCS). From 2007 to 2012, the NRCS obligated more than $91 million in California for conservation practices to address soil erosion and sedimentation on agricultural land. These practices are recommended to reduce erosion, prevent the transport of sediment, or trap sediment before it leaves the farm or field.

USDA Forest Service. Overall, watershed restoration project costs on national forests are close to $2,000/acre, and most of these projects have the benefits of reducing erosion and sediment transport. Meadow restoration using the pond and plug approach is about $1,000/acre. Road decommissioning costs about $16/cubic yard of sediment (reduction in potential erosion).

Los Angeles County Flood Control District (LAFCD). Based on the alternatives included in the LACFCD's Draft Sediment Management Strategic Plan (April 2012), the cost to manage the Strategic Plan's 67.5-mcy planning quantity could be as much as $1.2 billion over the 20-year planning period, 2012 to 2032.

U.S. Bureau of Reclamation (USBR) and U.S. Bureau of Land Management (BLM). Gravels are added to Northern California rivers to aid in the anadromous salmon run each year. The amount of gravels added depends on the budget allocated each year. Such gravel additions are occurring in the upper Sacramento River area (i.e., Clear Creek), and in other rivers such as the American River, Yuba River, and Stanislaus River. The costs per ton of gravel added depends upon such factors as the method of placement, tonnage of gravel placed, and how the gravel is placed (e.g., dump trucks dumping gravel directly into river, lateral berms laid alongside the streambed at low water, or sluicing a mix of water and gravel directly into the river). Typical tonnages added may vary from 5,000 to 10,000 tons and more per application. Also, the U.S. National Fisheries Service specifies the amount of cleaning (washing) that has to be done to the gravels prior to application, and the grain size distribution of the gravels, which adds to the cost.

Major Implementation Issues

The issues for implementing sediment management are similar to those experienced by related resource management strategies including:

- The need to balance environmental impacts, social impacts, feasibility, and cost.
- Availability and affordability of land.
- Different stakeholders have different needs and different understandings of the need to manage sediment.

- Local managers implementing site-specific solutions without consideration of the regional backdrop and how regional processes affect the local conditions.
- Stakeholders and regulators lack a complete understanding of the different natural regional sediment regimes and attempt to address issues on a statewide basis.
- Urbanization and other structural limitations may preclude introduction of natural regimes.
- Supply/demand regarding extracted sediment in terms of quantity and timing, sediment type, and use. Beneficial use is contingent or recipients for managed sediment.
- Conflicting federal, State, and local regulations, agency missions, and regulators' unwillingness to compromise navigate these conflicts for the good of a region.
- Significant resistance by some local interests concerned with siting and transfer of impacts. Lack of advocacy to counter negative attitudes, e.g., "don't see, don't care."
- Budget constraints, including the need to find funding source to pay for the incremental costs of RSM.

Sustainability issues facing the three management approaches — sediment source management, sediment transport management, and sediment disposition management — follow.

Sediment Source Management

Lack of Techniques for Coarse-Grained Sediments Management

There is a desire for the coarse-grained fraction of the natural supply of sediments (sand and gravel), but not the fine-grained sediments (silts and clays) from the watershed to enter the streams and rivers so they can replenish these sediments in fish spawning areas, and also move toward the ocean thereby replenishing the sand along the coastal beaches. Research is needed in this area because not many techniques currently exist for coarse-sediment bypassing in inland watersheds. One project in the Bay Area, Flood Control 2.0, recently funded by the EPA Water Quality Improvement grant program, is examining this question. The project will be underway during the next four years and will examine the coarse-grain load in Bay Area flood channels, characterize the channel configurations and constraints, and then identify ways to move coarse-grain sediment through the channels to the shoreline or to develop bypass areas where the sediment is diverted into habitat areas where it is much needed.

In particular, efforts must be made to keep coarse-grained sediments available and clean in fish spawning rivers and streams. Erosion in unstable watersheds brings fine-grained sediments into the channels which may settle and cover the coarse-grained sediments needed for spawning, thus eliminating them from use in the spawning process. This web site, published by Joseph M. Wheaton, describes these needs: http://www.joewheaton.org/Home/research/projects-1/past-projects/spawning-habitat-integrated-rehabilitation-approach-shira-.

Barriers to Supplying Coarse-Grained Sediments to the Coastal Beaches

Many of the beaches along the coastline are receding because their natural supply of coarse-grained sediments from inland rivers has been stopped by dams, extracted for use, deposited on impermeable pavements, coastal armoring, in-stream sand and gravel mining, stormwater controls, changes to the ground surface, and other land use practices.

Instream sand and gravel mining removes a resource that downstream environments need. This situation is anticipated to become worse and accelerate with sea level rise. As noted above, the CSMW is working toward this effort, but challenges remain as agencies aim to work collaboratively, identify the necessary funding, and overcome the traditional jurisdictional conflicts that create misalignment of policy and regulation. Current Corps policy for placement of dredge materials is the lowest-cost alternative which is not always where it could be used best. Sediments can also be used to restore the template of flood protection and in some cases, operations can be moved out of the stream or a mitigation fee can be imposed.

Along the coast, beach nourishment has usually been undertaken by combining the USACE’s or other dredgers’ maintenance dredging of sandy areas and pumping it or placing adjacent to or directly on the shoreline for distribution either via wave action or by mechanical means. This practice has been well received, however funding remains minimal. Even with these successes, a challenge to beach replenishment occurs when material must be transported over land through beach neighborhoods in order to get to the beaches. In some California locations, sandy beaches, primarily used for recreation, are human-made and require continual replenishment, maintenance, and support.

Cost Allocation

The issue of whose budget pays is a major barrier to reuse of any kind. Often reuse is not only environmentally beneficial, but also presents the optimal use of society’s funds. Even then, if the dredging budget will not pay for any increase in placement costs compared to disposal, and if the reuse site will not share some of the costs for receiving otherwise free material from the dredging project, the reuse does not occur. A USACE publication addresses this problem, which is available at http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/upload/2009_02_27_oceans_ndt_publications_2007_fed_standard.pdf.

Additionally, current USACE policy for placement of dredged material requires the lowest cost alternative which typically means transport to the location (e.g., beach) closest to the dredge area. Lack of broader policy discussion of this general issue is a lost opportunity to recommend to the Legislature to do a number of things. For example, the Legislature should encourage congressional action to revise how the Harbor Maintenance Trust Fund is distributed and to continue support or even increase funding to entities such as the Coastal Conservancy to share costs with USACE for dredging projects. Cost-benefit ratio for dredge disposal incremental (NED).

Controlling Excessive Sediment from Entering Eutrophic Waterways

Eutrophic waterways typically have a lot of minerals and organic nutrients that are used by plants and algae. They often appear dark and have poor water quality. This occurs when certain nutrients, such as phosphorus, are absorbed on fine-grained sediments and carried into the waterways and lakes. These nutrients can cause algal blooms to be out of control in a lake which then creates a lack of oxygen resulting in fish kills. The sediments also result in a reduction of light and clarity in lakes, thereby harming the food chain and also reducing the aesthetic quality of the lake. Controlling these conditions is challenging and failing to do so is especially harmful to Lake Tahoe.

Implementation of Regional Sediment Management

There are obstacles to the practical implementation of RSM. RSM requires a long-term, multi-year watershed view for planning. Yet, it may be difficult for stakeholders and regulatory agencies to adopt long-term views and without the necessary scale. Federal, State, and local regulations are sometimes in conflict with each other. Successful RSM requires compromises from everyone. Regulators often do not offer a compromise due to statutory requirements, not recognizing others' jurisdiction, and fear of exposure to third party lawsuits. Additional challenges for RSM are finding re-use projects/activities that occur at the same time that the sediment needs to be removed, long distances between potential users and the sediment source, and opposition from inhabitants/stakeholders. CSMEs Costal RSM Plan program aims to address many of these issues by providing a cogent, strategic methodology to address sediment imbalance issues within the specified region using RSM.

Limited Options Due to Other System Requirements

In some cases, the optimum sediment management approach may be precluded due to other system requirements or previously implemented decisions and goals.

As an example, a major shift in land use and population patterns may not be feasible. On a specific project level, large amounts of sediment already accumulated behind reservoirs prohibit the immediate implementation of a different approach to sediment management (e.g., a reservoir may need to be cleaned out to its original condition before a sediment flow-through approach can be implemented).

Also important is the instream sand and gravel mining industry, which, according to some authors (e.g., Magoon) may represent the largest source of downstream loss, but is also providing important benefits to the local economy and source materials for multiple critical uses.

Sediment Transport Management

The discipline of sediment transport management is emerging. Much remains to be learned about the best ways to manage for instream sediment quality objectives to prevent aquatic organisms from being smothered by sediment while also providing sediment for downstream processes and needs.

Lack of Monitoring on Stable (Reference) Sediment Conditions in Watersheds

Altered channels have changed natural hydrogeomorphology and natural sediment processes. There is a benefit in achieving and maintaining watersheds in a stable condition as it relates to the generation and transport of sediments from the land surface to the surface streams. This requires understanding (assisted by geomorphic assessments on channels) and monitoring to determine when watersheds are stable or unstable. Management without these tools causes stream channels to degrade in their geomorphic form and they will not support the native aquatic biological habitat. This affects domestic water supplies (filtration). Unstable sediment conditions may also result in disruption of flood control structures.

Achieving Broad Support for Establishing and Implementing Biological Objectives in Streams

The State Water Resources Control Board is establishing biological objectives, which will include those for suspended sediment as well as deposited sediments (see http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml). Excessive sediment in streams, as well as lack of natural sediment loads, can be detrimental to the aquatic life. Achieving broad support for establishing and implementing biological objectives is sometimes met with resistance.

Sediment Deposition Management

Sediment impacts through turbidity, dredging, or burial are also of concern in the coastal environment. Dredging has the potential to destroy habitat and biota currently residing in that habitat, while placement of sands has the potential to bury biota at the placement area or downcast from it. Both of these activities have the potential to create turbid conditions that if are not abutted, could create adverse conditions for filter feeders, visual predators, and photosynthesis. The CSMW's Biological Impacts Analysis and Resource Protection Guidelines discusses these potential impacts in detail, as well as recommending methodologies to minimize such impacts.

Securing Disposal/Placement Locations

Finding disposal locations has become increasingly difficult and expensive due to development of nearby land, regulatory constraints/requirements, or opposition from those adjacent or along the haul routes to the deposition sites.

Another challenge to disposing of/reusing dredged sediment on dry land is dewatering the sediment. Due to the high content of water if the project is hydraulically dredged, the dewatering areas need to be quite large and a region may not have sufficient space available.

When dredged material is placed at an upland dewatering or stockpile site, often future beneficial uses are not known until a particular reuse is proposed and the Regional Water Quality Control Boards analyze the sediment quality data that was collected during dredging. This is because sediment that may be chemically suitable (considered to be “clean enough”) for one kind of reuse may not be suitable for other kinds of reuse. Often this results in delays for projects wanting to reuse the sediment, and can also constrain the emptying and use of the storage sites for future projects.

Handling Contaminated Sediments

Management of contaminated sediments may be challenging. There are limited resources for cleaning of the sediments and disposal of containments taken from contaminated sediments. The USACE has a National Center of Expertise for handing contaminated sediments at http://el.erdc.usace.army.mil/dots/ccs/ccs.html.

Contaminated Sediment Management

The potential for contamination is a consideration whenever dealing with sediments, whether these are in upper watersheds or in ports and harbors. When a project or a watershed has to contend with contaminated sediment, special considerations need to be applied. Even contaminated sediment can often be reused, but a more limited set of potential uses for that sediment may be available.

Reuse Challenges

Appropriate reuse is sometimes cost-prohibitive. Challenges to using sediment for beneficial uses include finding beneficial use projects that coincide with the timing of sediment removal, long distances between the sediment removal site and the beneficial use site, offloading equipment needs, encountering regulatory obstacles, and encountering steep disposal fees at the beneficial use site.

Regulatory Requirements

Regulatory and management frameworks involving sediment typically are designed to support specific uses. As a result, they involve multiple agencies and jurisdictions that are not necessarily accommodating of the complexities of managing all the aspects of sediment sources, transport, and deposition. As a result, sediment-related projects and/or multiple benefit projects may not be feasible due to timing, costs, and conflicts related to the desired deposition of the sediment. Regionally, the LTMS program previously described provides a cooperative framework for testing, permitting, and beneficial reuse projects. The LA-CSTF is a similar interagency regulatory group. Significant effort and energy is required to maintain such cooperative and collaborative efforts when dealing with dredging and beneficial reuse projects. CSMW also functions as a clearinghouse for member agencies to identify sediment-related activities of interest to other agencies.

Data Availability

A number of issues related to integrated management and better planning and coordination could be improved with better data availability. For example:

- Better planning and decision-making could occur with coordinated mapping efforts to allow agencies to better consider upstream and downstream impacts prior to decision-making.
- Ongoing monitoring would allow better adaptive management and an evaluation of management methods being used.
- Improved forecasting and modeling would support long-term and strategic planning.
- Development of sand and sediment budgets would assist agencies in planning and reduce regulatory conflicts.

Data challenges can be addressed. For example, CSMW maintains a Web site designed to make as much information as possible to costal sediment managers. In addition, there are many Web sites that are devoted to specific topics that CSME has been involved with since 2003. These range from a topical library containing links to relevant reports to a searchable database of references. A spatial database containing numerous data layers is at http://www.dbw.ca.gov/CSMW/default.aspx.

Sediment and Climate Change

Climate change is already occurring and it is projected to continue to alter temperature and hydrology patterns in the state. Climate change studies project an increased frequency of extreme weather, higher temperatures, larger and more frequent wildfires, longer droughts, and more precipitation falling in the form of rain than snow. These changes will bring shifts in vegetative species, heighten soil exposure, and will cause flooding to already vulnerable lands and coastlines, adding a heavy mix of sediment and debris to stormwaters. Coupled with sea level rise and surge, which increases coastal erosion (e.g., more than just beach erosion, and coastal flooding, climate change will amplify the already difficult task of sediment management. Drought and climate change alter permeability and other physical characteristics of sediment. Increased carbon dioxide levels may influence soil chemistry.

Adaptation

Adaptation will necessitate projecting where excessive sediments will source and accumulate, and it is also necessary to build controls that will allow for effective management of those sediments. With climate change expected to bring wetter winter and drier summers, erosion will become an even greater threat to California lands and sediment management. Several adaptation strategies may provide benefits in light of climate change.

In some places, floodplain restoration is feasible. This tactic allows for natural deposits of beneficial sediment and serves dual purposes of managing sediment and replenishing soil. Excess, clean sediment can be used beneficially on eroding beaches and agricultural lands, augmenting natural processes. The Coastal Commission is also funding pilot projects for growing wetlands to protect against surge.

Managed retreat is also a tactic that can be used to manage impacts associated with changing beach width caused by climate change.

Warmer temperatures and higher levels of CO_2 may, in some cases, lead to increased vegetation. Vegetation can minimize runoff and lessen erosion, preventing sediments from entering waterways. Effective management of landscapes including planting heat- and drought-tolerant native vegetation around waterways will minimize sediment loads.

Mitigation

Sediment management is a continuous process that can result in high greenhouse gas (GHG) emissions. Dredging and channel clearing is necessary to ensure adequate capacity for flood protection, water supply, and navigation, but is a constant source of GHG emissions from fossil fuel-powered equipment. Ports in some areas have begun to convert to shoreside electric power that could be sourced to renewable energy as more dredges use electric power, but this will take a major industry effort to convert to a different system. Additional analysis should be undertaken to fully recognize the value of beneficially reusing dredged sediment in habitat projects, and the carbon sequestration capabilities of marshes and riparian habitats. Once these analyses are completed, projects can evaluate whether the GHG created by dredging are fully offset by the beneficial use project.

Recommendations to Facilitate Sediment Management

New recommendations for sediment management may increase costs and/or the amount of time needed to obtain permits. All new sediment recommendations should be strongly evaluated to determine to what extent they could inhibit important water/flood projects and activities. If impacts may occur, some form of mitigation for these effects should be included when implementing any given recommendation.

Policy and Regulatory Reconciliation

1. The State and USACE should convene a stakeholder working group that includes flood protection and water supply entities to recommend methods to overcome sediment management regulatory conflict and encourage long-term thinking, including the issuing of permits that match the time horizon for any established sediment management plan. The stakeholder working group should consult and build upon the successes of the CSMW, because they have tackled many of the issues in a coastal setting that will be encountered by those seeking to implement RSM in inland areas.

2. The USACE, Natural Resources Agency, California Environmental Protection Agency, Department of Finance, Governor's Office of Planning and Research, and the California Water Commission should convene a task force or stakeholder working group to recommend methods for sediment management cost allocation. Often reuse is not only environmentally beneficial, but also presents the optimal use of funds.
   A. The stakeholder group should also evaluate needs for outreach and education on sediment management and offer recommendations for next steps to address those needs.
   B. Specific focus should be given to cover the incremental costs of RSM.

Sediment Source Management

3. The Governor's Office of Planning and Research should develop model general plan guidelines that support optimum sediment source management.
4. Federal, tribal, State, regional and local agencies and stakeholders should support and participate in Regional Sediment Management for those sediments which must be dredged to keep the waterways and other facilities open to navigation or to support flood control efforts. Also, there should be support of those efforts to use that sediment beneficially within regions. One possible use of the sediment is levee construction that can direct the floodwater to the most desirable location.
5. The State Lands Commission and other responsible agencies should scrutinize instream and beach Sediment Mining Permits. The Commission should evaluate impacts of sediment-mining permits on a case-by-case basis, which allow the removal of coarse-grained material directly from stream beds or from coastal beaches. While such permits may be satisfactory in some instances, in other instances such permits reduce the sediment needed for fish spawning beds and for beach replenishment.
6. The State should implement the requirements recommended by the California Association of Storm Water Quality Agencies (CASQA) for stormwater discharge control programs associated with sediment management which
   A. Are technically and economically feasible.
   B. Provide significant environmental benefits and protect the water resources.
   C. Promote the advancement of stormwater management technology.
   D. Are compliant with State and federal laws, regulations, and policies. Reducing or controlling stormwater discharges keeps watershed and industrial pollutants from running into the waterways, thereby improving water quality.
7. The Regional Water Quality Control Boards should work with stakeholders to secure broader support of sediment water quality requirement efforts and promote development of stakeholder-based implementation plans to address excessive sediment problems.

Sediment Transport Management

8. The State should support research and design of fine-grained and coarse-grained sediment bypass structures. This will allow the coarse-grained sediment to be separated and either enter the streams and serve its many beneficial uses there, such as for fish spawning grounds and the restoration of coastal beaches, or be trapped in detention ponds where it can be excavated and used beneficially. The fine-grained sediment will be separated and can be used for wetland establishment or other uses. The separation and removal of fine-grained sediment with their attached nutrients can help improve the water quality in lakes having excessive eutrophication.

This work will need to account for water quality requirements and other interests, such as fishing and recreation.

9. The State should encourage the use of remote sensing as a tool for sediment transport management.
10. The State should support the use of watershed mathematical models, when the occasion demands, which can track sediment from source to transport in the streams. Such models (such as SWAT, HEC-HMS, and HSPF) need adequate calibration and validation, but once calibration is done, these models can help to manage the sediments throughout the watershed. The watershed model can also predict the concentrations of other water quality substances in the water.
11. The Natural Resources Agency and California Environmental Protection Agency should implement, as much as possible, an integrated approach to achieve the maintenance of stable watersheds. A stable watershed is one where sediment yield mimics the natural sediment production that would occur in the absence of anthropogenic conditions. If the watershed is not stable, assist in efforts to make it so.

Sediment Deposition Management

12. Where feasible, the State in cooperation with the local sediment management agencies should determine the Sediment Yields of Watersheds when downstream sediment problems are becoming an issue. This type of monitoring may not be feasible in undeveloped, highly-erosive mountain areas. These yields (such as in tons/square mile/year) can be determined at monitoring sites, which have matching pairs of suspended sediment concentrations and instantaneous flow rate measurements. Knowing the sediment yields will help to manage extraction and dredging budgets for the navigation channels and other non-navigation facilities.
13. The Regional Water Quality Control Boards in cooperation with the local sediment management agencies should expand use of regionally-based sediment screening criteria so that agencies could know sooner what the use of the dredged material could be and plan accordingly. Establish potential uses of dredged material, depending upon its quality, in advance. The upland sites receiving dredged material can then be emptied sooner and become available for additional dredged material. This will assist in maintaining the shipping channel in operational condition.
14. The State Lands Commission and DWR should prepare sand budgets for each watershed when downstream sand availability issues are occurring. Comparisons of these sand budgets over time for each watershed will tell of the effect of source Best Management Practices in affecting sand transport, will be of use in determining how well sand is moving toward the coastal beaches, will allow comparison of sand generation in the watershed to that removed by in-stream sand removal permits, and will tell which watersheds are the best in generating sand. These sand budgets should include the sand budgets developed for coastal areas, including the regional sediment budget studies conducted by UCSC for CSMW.
15. All affected jurisdictions should work with or through the CSMW, because it is preparing coastal RSM plans for most of the littoral cells along the coast.
16. The State should support and provide incentives for expanding successful interagency models to cover dredging projects throughout the state. Identifying beneficial reuse opportunities that support RSM goals should be a key objective of the State's involvement.
17. The State should develop a funding source to encourage and support beneficial reuse projects, specifically those that enhance, restore, or support habitat including beach nourishment and

wetland restoration projects. State funding can be partnered with federal and private funds to support these efforts.

18. The State may also consider ways to encourage beneficial reuse of sediment without State funding. Specific ideas include providing a tax credit or mitigation credit when sediment is reused beneficially rather than treated as a waste product.
19. The State should enable funding for special districts and local governments to undertake sediment management actions. This could include the ability to levy taxes for sediment management, similar to infrastructure districts.
20. For sediment removal projects from facilities that capture sediment from undeveloped watersheds (e.g., some dams and debris basins), State agencies should allow pre-testing to facilitate deposition of sediment at solid waste landfills, inert landfills, and other potential deposition sites, which otherwise may require testing and affect beneficial use of sediment, especially in emergency situations.

Data Acquisition and Management

21. Federal and State governments should support development of guidelines to identify when geomorphic assessments of streams for watershed stability are appropriate to prevent undue delays in processing permits and ensure that studies are scaled to project size.
22. The Federal and State governments should support sediment and flow monitoring programs of others if needed to determine the sediment yields from a watershed and sediment budgets for downstream areas. They should also establish monitoring protocols that produce scientifically-defendable data of comparable quality throughout the state. Such monitoring will add to the water quality data base of the waterway.
23. The Federal and State governments should support modeling and monitoring for sediment dynamics in estuarine and near-shore (littoral cell) environments when understanding estuarine and near-shore sediment transport issues is key to adaptive management, infrastructure protection, and habitat restoration.
24. The State should expand efforts for a sediment data exchange and cooperate with others who may be obtaining sediment data in a watershed so that a common database is used that is accessible to all users. Stakeholders should be convened to establish data needs and requirements. CSMW has developed a GIS database and associated web viewer, and is working with the Ocean Protection Council to incorporate their spatial data into the State Geoportal, currently under development. The State Geoportal is envisioned as a one-stop location for most of California agencies' geospatial database.
25. All responsible agencies should utilize a common GIS mapping framework and use GIS to overlay maps relating sources of excessive sediment production in watersheds with areas having sediment problems in the stream in those watersheds.

PLACEHOLDER Box 26-3 Case Study: Sediment Management Related to Recreational Use

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

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Table 26-1 Agency Roles and Activities in Sediment Management

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Federal	US Department of Agriculture (USDA) Forest Service Natural Resources Conservation Service) Dept. of Interior (DOI) Bureau of Land Management US Geological Survey Park Service Defense USACE	Land Managers, Advisors	Support California land management practices that incorporate erosion control and sediment management. Landscape Conservation Cooperatives
Federal	Dept. of Interior (DOI) US Fish and Wildlife Service Dept. of Commerce NOAA US EPA USACE	Regulators Advisors	Oversight for Dredging, fisheries and TMDL issues
Tribal	Tribal Governments	Land Managers, Planners	Plan and manage for sediment management considerations.
State	CalFIRE Board of Forestry and Fire Protection (BOF) State Lands Commission State Parks Fish & Wildlife	Land Managers Advisors Planners Regulators	Promotion of sediment management through best forest management practices. For over 20 years a group of advisors called the Monitoring Study Group (MSG) has, and continues, to: (1) develop a long-term program testing the effectiveness of California's Forest Practice Rules, and (2) provide guidance and oversight to the California Department of Forestry and Fire Protection (CAL FIRE) in implementing the program. The MSG has sponsored significant research on sediment management. This research informs CAL FIRE funded monitoring efforts designed to ascertain if forest practice rules, reducing unnatural sediment loads and protecting beneficial uses of water are being implemented and are effective.
State	Department of Food and Agriculture Department of Conservation Fish and Wildlife The University of California Extension Farm Advisors	Advisors Grant Administrators Training & technical Assistance	Provide significant leadership in source sediment management through the development of Best Management Practices (BMPs)

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
State	Water Boards	Regulators Training & technical Assistance	Protect water quality through the issuance of regulations and permits which also serve as National Pollutant Discharge Elimination System (NPDES) permits for point source discharges subject to the Clean Water Act. Permits related to sediment control include stormwater permits for municipal stormwater systems, highways and other thoroughfares and construction activities. Permits require the implementation of best management practices (BMPs) at constructions sites, outreach and education to residents, and consideration of the principles of low impact development for redevelopment and new development sites. Non-point source (NPS) pollution can include sediment or pollutants carried by sediment. NPS pollution is divided into the following six categories: (1) agriculture; (2) forestry; (3) urban areas; (4) marinas and recreational boating; (5) hydromodification activities; and (6) wetlands, riparian areas, and vegetated treatment systems. The Water Boards administers grant funding to develop and implement management practices to address NPS pollution such as development and implementation of the California Rangeland Water Quality Management Plan (http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf).
Regional	Sierra Nevada Conservancy	Planning Financial Assistance Training & technical Assistance	Promotion of land use practices that support optimum source sediment management
Regional	Tahoe Regional Planning Agency	Planning Regulation	Promotion of land use practices that support optimum source sediment management
Local	Local Governments, Districts, Water Agencies, Reclamation Districts and Planning Commissions	Planning Regulation	Promotion of land use practices that support optimum source sediment management. Some local governments (city and county) support Low Impact Development (LID), including it as part of their planning and development ordinances. LID features design elements, including hydromodification, that address sedimentation at the source. Resources, including model regulations, are available to help municipalities interested in incorporating sediment source management into their planning portfolios. Local governments may also be involved in flood protection and water supply. (http://www.epa.gov/owow/NPS/lidnatl.pdf, http://www.epa.gov/region1/topics/water/lid.html, http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf, and http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf & http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf).

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Local	Cities Counties JPA's Commission's	Advisors	Develop a land stewardship ethic that promotes long-term sustainability of the state's rich and diverse natural resource heritage.
Local	Resource Conservation Districts	Planning, technical and financial assistance	Resource Conservation Districts (RCDs) implement projects improving sediment management on public and private lands and educate landowners and the public about resource conservation. They work together to conduct: • Watershed planning and management. • Water conservation. • Water quality protection and enhancement. • Agricultural land conservation. • Soil and water management on non-agricultural lands. • Wildlife habitat enhancement. • Wetland conservation. • Recreational land restoration. • Irrigation management. • Conservation education. • Forest stewardship. • Urban resource conservation.
NGO	California and local Farm Bureaus California Rangeland Trust TNC	Advisors Advocates Training & technical Assistance	Information development and dissemination, policy advocacy Land Holding Services
NGO	California Association of Storm Water Quality Agencies (CASQA)	Advisors Advocacy Training & technical Assistance	Assists the Water Boards and municipalities throughout the state of California in implementing the National Pollutant Discharge Elimination System (NPDES) stormwater permits. One of the accomplishments of CASQA has been the development and dissemination of Best Management Practices (BMP) Handbooks. The BMPs help reduce unwanted delivery of sediment. The handbooks are designed to provide guidance to the stormwater community in California regarding BMPs for a number of activities affecting water quality and sediment management, including New Development and Redevelopment, Construction Activities, Industrial and Commercial Activities, and Municipal Activities (CASQA Web sites: http://www.casqa.org/ and http://www.cabmphandbooks.com).

TYPE	AGENCY	ROLE	SAMPLE ACTIVITES
Private Interests and Land Managers	PG&E, Southern California Edison and other major private utilities with large land and water holdings and infrastructure. Tejon Ranch. Irvine Ranch, etc. Timber & Rail companies (e.g. Sierra Pacific, Catellus Corporation, a successor to the Southern Pacific Land Company and affiliated with Santa Fe Pacific) Agriculture	Land Management	Pacific Forest and Watershed Lands Stewardship Council (PG&E) Irvine Ranch Conservancy Tejon Ranch Conservation and Land Use Agreement

Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

[photo to come]

Box 26-1 Debris and Sediment

The Sediment Resource Management Strategy (RMS) relates to organic materials. However sediment and debris are often comingles.

Approximately 80 percent of marine debris in the world's oceans originates from land-based sources- primarily trash and debris in stormwater and urban runoff. Studies have found that significant quantities of small plastic debris originating in urbanized land areas pollute the Pacific Ocean both near-shore and on beaches and segments of the ocean thousands of miles away from human habitation.

Studies of debris in Southern California coastal waters demonstrate that significant quantities of trash and debris originate from urban areas and are comprised of pre-production plastics from plastic industrial facilities, trash and litter from urban areas, and boating and fishing-related debris.

More about this topic may be found in the Pollution Prevention and Stormwater-Urban Run Off RMS chapters.

Source: California Coastal Commission and Algalita Marine Research Foundation, n.d.

Box 26-2 Definitions

Suspended load is the portion of the sediment that is carried by a fluid flow which settles slowly enough such that it almost never touches the bed. It is maintained in suspension by the turbulence in the flowing water and consists of particles generally of the fine sand, silt and clay size.

Bed load describes particles in a flowing fluid (usually water) that are transported along the bed of a waterway.

Wash load is the portion of sediment that is carried by a fluid flow, usually in a river, such that it always remains close the free surface (near the top of the flow in a river). It is in near-permanent suspension and is transported without deposition, essentially passing straight through the stream. The composition of wash load is distinct because it is almost entirely made up of grains that are only found in small quantities in the bed. Wash load grains tend to be very small (mostly clays & silts but some fine sands) and therefore have a small settling velocity, being kept in suspension by the flow turbulence.

Box 26-3 Case Study: Sediment Management Related to Recreational Use

Off-highway vehicle (OHV) use is a popular form of recreation in California. State and federal agencies provide recreational areas for this purpose. These OHV recreation areas need to implement a range of storm water best management practices to protect water quality. Additionally, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted storm water. With limited resources, maintaining and policing these areas can be a challenge.

In 2009, the Central Valley Water Board found that portions of the Rubicon Trail located in El Dorado County were severely eroded, erosion was accelerated by OHV use and sediment was being discharged to surface waters. (see following 3 photos provided courtesy Monte Hendricks) To address this problem as well as other OHV related water quality issues, the Central Valley Water Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2009) to El Dorado County and Eldorado National Forest to develop and implement plans to improve management of the trail and protect water quality.

PLACEHOLDER Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

PLACEHOLDER Photo B [title to come]

The Rubicon Trail Foundation, in response to critisms over OHV use of the Rubicon Trail, has been involved in restoration activities and, in testimony to the Central Valley Water Board, provided some photos of improvements. The following three photos (also see pdf of the actual slides from the testimony to the Central Valley Water Board) show before, during and after photos of an eroded site.

In 2012, the Central Valley Water Board found that sediment disturbed by recreational vehicle activity and transported in storm water runoff to Corral Hollow Creek was a water quality problem at the Carnegie State Vehicle Recreation Area. The Board also identified metals, such as copper and lead, as a potential concern. To address these problems, the Board issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2012) to the California Department of Parks and Recreation (State Parks). The Order recognized that State Parks had developed a Storm Water Management Plan that describes the best management practices that need to be implemented to address erosion and sedimentation. The Order required State Parks to and implement the Storm Water Management Plan update.

PLACEHOLDER Photo C Off-Highway Vehicle — Sediment Settling Pond

— Betty Yee, Central Valley Regional Water Quality Board

Photo A Rubicon Trail, U.S. Department of Agriculture Forest Service Land

[photo to come]

Photo B

[title and photo to come]

Photo C Off-Highway Vehicle — Sediment Settling Pond

[photo to come]

Box 26-4 Case Study: Los Angeles County Flood Control District — Impacts of the 2009 Station Fire

In the 1800s and early 1900s, the Los Angeles Region experienced catastrophic floods that resulted in loss of life and property. Consequently, in 1915, the California State Legislature adopted the Los Angeles County Flood Control Act. The Act established the Los Angeles County Flood Control District and empowered it to provide flood risk management and conserve flood and storm waters. The Flood Control District encompasses most of Los Angeles County, including the highly erosive San Gabriel Mountains as well as other mountain ranges. The Flood Control District operates and maintains 14 dams and reservoirs, 162 debris basins, 500 miles of open channel, and other infrastructure.

Given the region's highly erosive mountains and the existing system, managing flood risk and conserving water goes hand in hand with removing and managing the sediment that accumulates at the facilities. Sediment is delivered to the facilities as a result of runoff in the mountains picking up and carrying material eroded from the mountains. The amount of sediment that reaches a facility any given year depends on the size of the watershed, the watershed's vulnerability to erosion, watershed conditions (such as vegetated watershed versus burned watershed), and weather conditions (such as amount and intensity of rain).

Wildfires greatly increase the amount of runoff and erosion from mountainous watersheds. As much as 120,000 cubic yards of sediment and debris have been produced per square mile of a burned watershed after a major storm. The first four years after a fire have proven to be the most critical in terms of the potential for increased delivery of sediment and debris to the Flood Control District's facilities. The effects of wildfires were taken into consideration during the design of the dams under the jurisdiction of the Flood Control District and continue to be considered for today's operations.

The Station Fire of 2009 was the largest fire in Los Angeles County's recorded history, burning approximately 250 square miles. The fire started on August 26th and was not fully contained until October 16th. The burned watersheds resulted in a significant increase in the amount of sediment and debris eroding from the hillsides during storms and making its way into debris basins and reservoirs. After a short but powerful burst of rain in mid-November 2009, Mullally Debris Basin, which is located in the City of La Cañada-Flintridge and has a 9,400- cubic-yard capacity, filled up in 30 minutes. There were also storms in January and February 2010 that delivered tremendous amounts of sediment to the facilities. The images shown below illustrate the amount of sediment that reached Dunsmuir and Mullally Debris Basins as a result of the Station Fire and the storms of February 2010.

PLACEHOLDER Photos A-D Dunsmuir and Mullally Debris Basins

Immediately following the Station Fire and the 2009-2010 Storm Season, a total of approximately 1.2 million cubic yards (MCY) of sediment were removed from 38 debris basins in order to reduce flood risk for the communities downstream of those debris basins from subsequent storms that still had the potential to send overtopping flows into the debris basins. In addition, many k-rails were installed in the streets of the foothill communities to direct flows away from houses in the event of debris flows due to overtopped debris basins. Emergency operations involved day and night work and trucking of sediment through neighborhoods. The total amount of sediment removed that year is the largest amount removed in any year since the Flood Control District began managing sediment accumulation in debris basins in the 1930s. Notably, the amount of sediment inflow to debris basins is small compared to the amount of sediment that impacts the reservoirs the Flood Control District maintains.

The Station Fire burned significant portions of the watersheds of four reservoirs, as listed below.

- Big Tujunga Reservoir: 88 percent of the reservoir's watershed.
- Cogswell Reservoir: 86 percent of the reservoir's watershed.
- Devil's Gate Reservoir: 68 percent of the reservoir's entire watershed, 92 percent of the reservoir's undeveloped watershed.
- Pacoima Reservoir: 80 percent of the reservoir's watershed.

Based on the Flood Control District's records, 3 of the 4 reservoirs have had an additional 1 MCY of sediment accumulate in them, as detailed in the table below. The potential for high sediment inflows into both reservoirs and debris basins will continue until the watersheds recover.

Table A [title to come]

Reservoir	Date of last survey prior to or soon after Station Fire	Date of last survey [a]	Amount accumulated between subject surveys	Challenges
Big Tujunga	October 2009	August 2011	1.6 MCY	1,2,3,5
Cogswell	December 2009	August 2011	1.7 MCY	1,2,3,5
Devil's Gate	April 2009	March 2011	1.2 MCY	4,5
Pacoima	January 2009	September 2011	0.4 MCY	1,3,4,5

[a] As of June 2012

1 – Limited access ; 2 – Limited space at adjacent or nearby sediment placement sites; 3- Endangered species present downstream; 4- Conflicting environmental interests; 5- Long haul routes to facilities with available space

Another consideration at reservoirs is the amount of sediment already accumulated in them** and the capacity available for additional sediment accumulation that would not interfere with the dam's operations. Given the current volume of sediment and the high potential for large sediment inflows, the Flood Control District is planning sediment removal projects at the four reservoirs affected by the Station Fire. These projects are currently estimated to remove a total of 14 MCY of sediment over the next 8 years, with each project lasting 3 to 5 years and costing as much as $50 million.

** Significant amounts of sediment have accumulated in the subject reservoirs prior to the Station Fire (the same is true of other reservoirs operated and maintained by the Flood Control District). This is the result of a combination of issues, including the following:

- Diverse stakeholder interests, which result in different opinions on the "best" sediment removal, transportation, and placement alternative that should be used for a project.
- Conflicting regulatory requirements.
- Restrictions from other agencies.
- Costs.

— Greg Jaquez, LA Flood Control District

Photos A-D Dunsmuir and Mullally Debris Basins

[photos to come]

Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

Following is story about a proposal to remove a dam (http://www.sandandgravel.com/news/article.asp?v1=13621). While the San Clemente Dam no longer is providing the water supply function it was intended to meet, that may not be true for other dams in the State. For example, LA County has a lot of people (most of its 10 million population) depending on LACFCD's and Corps' dams for flood protection & water supply. This makes a discussion of sediment and dam removal essential to the water management discussion.

News - September 27, 2010

California American Water has filed an application with the California Public Utilities Commission requesting permission to remove the San Clemente Dam on the Carmel River in order to resolve seismic safety concerns associated with the dam and restore critical habitat for the steelhead trout.

"From an engineering and environmental perspective, this is a landmark project," said California American Water president Rob MacLean. "Our innovative method for dealing with the sedimentation behind the dam and the level of public-private cooperation which has made this plan a reality will serve as a template for the removal of other obsolete dams across the country."

California American Water is partnering with the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and the California State Coastal Conservancy to implement the dam removal project while minimizing cost to its ratepayers. California American Water has committed $49 million and the dedication of 928 acres where the dam is located as parkland.

The Coastal Conservancy and NOAA committed to raise the additional $35 million needed for the removal project through a combination of public funding and private donations.

The San Clemente Dam is a 106ft high concrete-arch dam built in 1921, 18 miles from the ocean on the Carmel River, to supply water to the Monterey Peninsula's then-burgeoning population and tourism industry. Today the reservoir is over 90 percent filled with sediment and has a limited water supply function.

In 1991, the California Department of Water Resources, Division of Safety of Dams agreed with a California American Water consultant's assertion that San Clemente Dam did not meet modern seismic stability and flood safety standards.

The Department of Water Resources and Army Corps of Engineers studied many ways to ameliorate the safety issues including strengthening the dam and removing it.

The January 2008 Final Environmental Impact Report and Environmental Impact Statement ("EIR/EIS") regarding San Clemente Dam's stability contains analysis of a Reroute and Removal Project, which would address the seismic and flood safety risks associated with San Clemente Dam by permanently rerouting a portion of the Carmel River and removing the dam.

Under this proposal, the Carmel River would be rerouted to bypass the 2.5 million cubic yards of silt that have accumulated behind the dam thereby avoiding dredging, which has been deemed infeasible.

The primary benefits of the Reroute and Removal Project are that it improves the Carmel River environment by removing the dam, which serves as a barrier to fish passage, and satisfies government agencies' concerns that strengthening the dam, as opposed to removing it, could further threaten the South Central California Coast Steelhead and violate the federal Endangered Species Act.

Source: Dredging News Online 2010

Box 26-6 Case Study: Clear Lake — Algae in Clear Lake

The Clear Lake Basin was shaped by a variety of processes over the last 1 to 2 million years. Scientists have recovered a nearly continuous sequence of lake sediments dating back 475,000. Other lake sediments in the region that date back to the Early Pleistocene, approximately 1.6-1.8 million years ago.

There is an excellent climate record from these cores for the last 127,000 years. The record documents a shift from pine dominated to oak dominated forests at the end of the Pleistocene Glacial Period 10,000 years ago, indicating a warming trend. The diatom sequence in these cores indicate that Clear Lake has been a shallow, productive system, essentially similar to the modern lake since the end of the Pleistocene Period.

The basin was created primarily from the stresses of the San Andreas Fault System, the eruption and subsidence of the Clear Lake Volcanics, and the erosion and deposition of the parent rock. The east-west extension of the fault system and vertical movements of the faults created and maintained the basin. Downward vertical movement within the basin created by these processes is at a rate approximately equal to the average sedimentation rate of 1/25 inch/year in the lake basin.

Since these rates are essentially equal, a shallow lake has existed in the upper basin for at least the last 475,000 years. If sedimentation rates were significantly different from the downshift, then either a deepwater lake or a valley would have resulted. Although the lake has changed shape significantly over this period, it has generally been located in the same area as the existing Upper Arm.

Clear Lake is a naturally eutrophic lake. Eutrophic lakes are nutrient rich and very productive, supporting the growth of algae and aquatic plants (macrophytes). Factors contributing to its eutrophication include a fairly large drainage basin to contribute mineral nutrients to the water, shallow and wind mixed water, and no summertime cold water layer to trap the nutrients. Because of the lake's productivity, it also supports large populations of fish and wildlife.

The algae in Clear Lake are part of the natural food chain and keep the lake fertile and healthy. Because of the lake's relative shallowness and warm summer temperatures, the algae serve another important purpose. They keep the sun's rays from reaching the bottom, thus reducing the growth of water weeds which would otherwise choke off the lake.

Along with Clear Lake's high productivity, algae in the lake can create a situation which can be perceived as a problem to humans. Algae are tiny water plants that cycle normally between the bottom and the surface, floating up and sinking down. During the day, algae generate oxygen within the lake; at night they consume oxygen.

Nuisance blue-green algae, however, can be a problem. From more than 130 species of algae identified in Clear Lake, three species of blue-green algae can create problems under certain conditions. These problem blue-greens typically "bloom" twice a year, in spring and late summer. The intensity of the blooms vary from year to year, and are unpredictable. The problem occurs when algae blooms are trapped at the surface and die. When this occurs, unsightly slicks and odors can be produced.

It does not appear that blue-green algae are a recent development in Clear Lake.

Sediment cores collected from the bottom of Clear Lake by the United States Geological Survey (USGS) indicate Clear Lake has been eutrophic with high algal populations since the last ice age, which ended approximately 10,000 years ago. The graph at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Algae+Pollen+in+Core.pdf shows the change in algae pollen over time from a core in the Upper Arm.

Livingston Stone, a fisheries biologist, visited Lake County in 1873 and reported to Congress that Clear Lake had significant algal populations at the time.

> It is a singular fact, illustrating the inaptness with which names are often given to natural objects, that the water of Clear Lake is never clear. It is so-cloudy, to use a mild word, that you cannot see three feet below the surface. The color of the water is a yellowish brown, varying indefinitely with the varying light. The water has an earthy taste, like swamp-water, and is suggestive of moss and water-plants. In fact, the bottom of the lake, except in deep places, is covered with a deep, dense moss, which sometimes rises to the surface, and often to such an extent in summer as to seriously obstruct the passage of boats through the water.

He further describes water conditions in September as:

> Fish and fishing are about the same as in August. The weather is a little warmer. No one fishes during this month except the Indians, who still keep after the trout. The water this mouth is in its worst condition. It is full of the frothy product of the soda-springs. A green scum covers a large part of the surface, and it is not only uncleanly to look at, but unfit to drink; and yet, strangely enough, this lake, which one would think uninhabitable by fish, fairly teems and swarms with them.

These descriptions appear to describe blue-green algae and conditions similar to that in the last 20 years. The “moss” described in the first passage could be rooted plants or the filamentous algae *Lyngbya*, which behaves in a similar manner. Regardless, this moss indicates a relatively clear lake if sunlight is penetrating sufficiently to promote growth of “moss” on the bottom. The full text of Stone’s writings about Clear Lake are available at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Livingston+Stone.pdf.

Other historical accounts indicate the lake was relatively clear through 1925. Substantial declines in clarity and increases in scum forming algae (blue-green algae) occurred between 1925 and 1939. An increase in nutrient loading from increased erosion, fertilizer and wastewater discharges due to urban and agricultural development were the probable causes of increased blue-green algal growth.

The advent of powered earthmoving equipment increased the amount of soil disturbance and facilitated large construction projects, such as the Tahoe-Ukiah Highway (State Highway 20), the reclamation of the Robinson Lake floodplain south of Upper Lake, stream channelization and the filling of wetlands along the lake perimeter. To support the development, gravel mining increased within the streams , further increasing erosion and sediment delivery to Clear Lake. During this time period, mining techniques at the Sulphur Bank Mercury Mine changed from shaft mining to strip mining, resulting in the discharge of tens of thousands of yards of overburden directly into Clear Lake.

Limnological studies of Clear Lake began in the early 1960’s to determine the causes of the high productivity in Clear Lake. It was found that the lake is nitrogen limited in the summer, with a great excess of phosphorus within the system. Phosphorus in the water column comes from both the annual inflows and nutrient cycling from the lake sediments. Nitrogen limitation does not affect many blue-green algae, as they were able to utilize (fix) nitrogen from the atmosphere, and consequently have an essentially unlimited supply of nitrogen. This gave these blue-green algae a competitive advantage, and *Anabaena* and *Aphanizomenon* dominated the lake during the summer. A third blue-green algae, Microcystis, also occurred in significant quantities. During this time period, it was also determined that iron was a limiting micro-nutrient.

Starting in the summer of 1990, lake clarity improved significantly. This improved clarity has continued until the present. The graph at http://www.co.lake.ca.us/Assets/WaterResources/Algae/Secchi+Depth$!2c+Upper+Arm.pdf shows the Secchi Depth (the depth into the water at which a black and white checked plate is visible) in the Upper Arm from 1969 through 2008.

During the 1991-1994 time period, University of California researchers led by Drs. Peter Richerson and Thomas Suchanek analyzed lake water quality data collected for the previous 15 years, conducted experiments and evaluated the Clear Lake system. Unfortunately, little data was available during the period of improved clarity since 1990. The “Clean Lakes Report” (http://www.co.lake.ca.us/Assets/WaterResources/Algae/Clean+Lakes+Report$!2c+1994.pdf) determined that excess phosphorus is a major cause, however, iron limits the growth of blue-green algae. The improved water clarity and reduced blue-green algal blooms continued into the new millennium. DWR data collected since the Clean Lakes Report was evaluated by Lake County staff in 2002. Surprisingly, phosphorus and total nitrogen concentrations in the lake did not change substantially when the lake clarity increased. Cursory review of the data did not provide evidence of chemical changes that led to the improved clarity and reduced blue-green algal blooms in Clear Lake.

Source: County of Lake 2010

Chapter 14. Surface Storage — Regional/Local — Table of Contents

Chapter 14. Surface Storage — Regional/Local

Surface storage is the term for the use of human-made, above-ground reservoirs to collect water for later release when needed. Surface storage has played a key role in California where the quantity, timing, and location of water demand frequently does not match the natural water supply availability. Many California water agencies rely on surface storage as a part of their water distribution systems. Reservoirs also play an important role in flood control and hydropower generation throughout California.

In addition, surface storage is often necessary for, or can increase the benefits from, other water management strategies, such as water transfers, conjunctive water management, and conveyance improvements. Some reservoirs contribute to water deliveries across several regions of the state while others provide only relatively local water deliveries. There are two general categories of surface storage reservoirs: (1) those formed by damming an active, natural river; and (2) those called offstream reservoirs, which require a human-made diversion or pumping of water from a river into storage.

Additional surface storage benefits can be developed by enlarging a dam and releasing the water it stores behind it, reoperating the releases from a dam (see Chapter 7 of this volume, "System Reoperation"), or modifying existing reservoirs. Smaller reservoirs typically store water only annually in the winter for supply use in summer, while larger reservoirs hold extra water over several years (known as carryover storage) as a reserve for droughts or other emergency supplies. In recent decades, reservoir operations have been most affected by the need to meet environmental regulations for the protection of affected fish species. Today, multiple-purpose surface storage projects balancing water supply, flood protection, hydropower production, water quality, and ecosystem needs are the norm.

The information in this chapter focuses on regional and local surface storage alternatives but does not include the major surface storage investigations of the State and federal CALFED Bay-Delta Program (CALFED), which are described separately in Chapter 13, "Surface Storage — CALFED."

Surface Storage in California

California has nearly 200 surface storage reservoirs greater than 10,000 acre-feet (af) with a combined storage capacity of more than 41 million af. These were tabulated in chronological order within Volume 4 of *California Water Plan Update 2009*, "Reference Guide," under the topic "Infrastructure" (California Department of Water Resources 2009). In addition, there are many more reservoirs smaller than 10,000 af that are used to provide for a wide range of water uses, such as stabilizing water delivery to customers or providing a backup supply for emergency needs.

Most of California's reservoirs were constructed more than 40 years ago; the number of new reservoirs built has steadily declined since the 1960s. Only six new water supply reservoirs were constructed in California in the 1980s and 1990s, and only three have been completed since 2000. Examples of recently completed surface storage projects servicing local or regional areas include:

- The U.S. Bureau of Reclamation's Warren H. Brock Storage Reservoir, located on the north side of the All-American Canal in Imperial County and completed in 2010.

- San Diego County Water Authority's Olivenhain Reservoir, completed in 2003.
- Metropolitan Water District of Southern California's Diamond Valley Reservoir, completed in 2000.
- The U.S. Army Corps of Engineers' and Orange County Flood Control District's Seven Oaks Reservoir, completed in 1999.
- Contra Costa Water District's Los Vaqueros Reservoir, completed in 1998.

The primary benefits of these new reservoirs include water supply reliability against catastrophic events and droughts, operational flexibility to meet peak summer water demands, water quality improvement, flood control, hydropower, and capturing excess flows.

A few enlargements of existing surface storage reservoirs have been completed since 2000 to meet anticipated future needs. Examples include the 60,000 af expansion of Los Vaqueros Reservoir by Contra Costa Water District completed in 2012; the 24,000 af expansion of Topaz Lake Reservoir on the California-Nevada border in 2008 to increase flood control; the 152,000 af enlargement of San Vicente Reservoir in San Diego County in 2006; and the 42,000 af expansion of Lake Kaweah reservoir in 2004 for flood protection and agricultural water supply.

Some surface storage has decreased across the state due to the removal of smaller, older, obsolete dams, primarily for the purpose of improving fish habitat and passage upstream. The California Department of Water Resources' (DWR's) Fish Passage Improvement Program, within the FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO), maintains a list of dams removed for fish passage purposes. DWR's June 2005 Bulletin 250, *Fish Passage Improvement: An Element of CALFED's Ecosystem Restoration Program*, describes structures removed to improve fish passage in California. One of the reasons that removal of existing dams is feasible is that newer, more efficient alternatives now serve the projects' original purposes for water deliveries or hydropower generation. In early 2010, a package of agreements was signed by many local stakeholder groups, three tribes, PacifiCorp (an electric power company), California, Oregon, and the federal government. This is leading to the removal of four hydroelectric dams on the Klamath River in Oregon and California. The removal will improve fish passage and possibly bring about a major fisheries restoration.

Throughout the past three decades, new regulations and legislation have required many reservoirs to be operated in a more environmentally friendly manner to improve downstream riverine habitats and fisheries. Specifically, many existing reservoirs have been reoperated to achieve ecosystem and river recreation benefits beyond the original project objectives.

As the competing water demands for agricultural, urban, and environmental needs have increased, the operational flexibility of California's various surface water systems has decreased. Today's water system managers face a complex array of competing demands on the use of limited reservoir storage, which potentially results in more water reductions during droughts.

The relative need for additional local surface storage development may be greatest in California's interior mountainous areas, such as the Cascades and the Sierra Nevada. Although much of the water used throughout the state originates in the mountains, these locations generally possess limited groundwater supplies, are particularly vulnerable to the impacts of climate change on hydrology, and have a shorter list of water management strategies available to meet local needs. This is largely due to geographic, hydrogeologic, or hydrologic limitations. Of these few strategies, new surface storage or enlargement of existing reservoir storage may hold the greatest potential for achieving local supply reliability objectives. Local surface storage development options also could include the reoperation of existing reservoirs through the development of water sharing or purchasing agreements with the downstream owners of existing reservoirs.

Potential Benefits

Many of California's reservoirs were originally built for one or two primary purposes, such as agricultural and municipal consumptive water use, flood control, or hydropower. However, over time the number of benefits asked of surface storage has generally expanded to include the following:

- Water quality management.
- Ecosystem management.
- Sediment transport management.
- River and lake recreation.
- Emergency water supply.
- System operational flexibility.

The presence of new surface storage allows water managers the flexibility to implement water management strategies more easily and more efficiently or to implement strategies simply not available without storage. Storage helps solve the temporal problem that occurs when the availability of water and the demand for water do not occur at the same time. Often regional conservation efforts are ineffective if any water conserved cannot be stored for later use. Storage allows water transfers between regions to occur at any time, not just when the water is needed for immediate use. In addition, water transfers early in the water year are generally less expensive, because of less demand, than transfers later in the water year. Surface storage is needed to enable and improve the effectiveness of conjunctive water management strategies by controlling the timing and volume of water ultimately conveyed for storage in groundwater basins.

Dealing with climate change impacts is a key concern for California's water purveyors. Climate change projections foresee more extreme weather, such as floods and droughts. More importantly, warming temperatures are expected to raise the snowfall elevation, causing more winter precipitation in the Sierra Nevada to occur as rainfall and creating larger and earlier runoff events. In addition, several million acre-feet of natural snowpack storage could be lost. By expanding surface storage capacity, water supply systems would have greater flexibility to capture the increased winter runoff and help control larger anticipated flood flows. Additional reserve storage would also allow water to be held over for all uses in dry years and droughts.

Potential Costs

Cost estimates for potential surface storage alternatives are not specified in this narrative because they vary extensively by region and specific project design. In most cases, the costs of multipurpose storage projects are shared by many beneficiaries and often include a State or federal cost-share component. The magnitude of individual project benefits and corresponding costs for new water supply, hydropower, flood management, and water quality, as examples, can be expected to vary significantly from project to project such that average cost information is not accurate.

Major Implementation Issues

Climate Change

Climate change projections indicate that California will experience more extreme weather, such as floods and droughts. At the same time, warming temperatures are expected to raise the snowfall elevation, causing more winter precipitation in the Sierra Nevada to occur as rainfall. This will lead to larger and earlier runoff events. As a result of these changes, several million acre-feet (af) of natural snowpack storage could be lost annually, reducing available water supply. In addition, the increasing severity of storms and increased runoff could overwhelm existing reservoir flood protection capacity and increase flood risks downstream.

Adaptation

Expansion of surface storage capacity can be an effective climate change adaptation strategy because increasing local and regional surface storage can provide greater flexibility for capturing runoff and managing supplies to meet increasingly variable future conditions. The ability to store water from wet years for use in dry years is critical to addressing increasing climate variability. Additional surface storage allows water to be held over from year to year as a hedge against dry years and droughts. Surface storage facilities south of the Sacramento-San Joaquin River Delta (Delta) allow water to be moved through the Delta when conditions allow it. Even if the water isn't needed immediately, the water can be stored for later use, providing additional protection from Delta supply interruptions and cutbacks. Surface storage provides unique climate change adaptation characteristics that are difficult to achieve with other management strategies: the ability to quickly detain and retain flood flows to protect downstream assets, and the ability to quickly release large quantities of water when demands increase or to meet instream temperature requirements.

Mitigation

Increases in greenhouse gas (GHG) concentrations in Earth's atmosphere are thought to be the main cause of current climate warming. Human activities, such as the burning of fossil fuels and deforestation, have been identified as the origin of higher GHG concentrations. Construction of surface storage reservoirs typically requires substantial construction and heavy equipment activity, which can emit large quantities of GHGs. In addition, offstream surface storage projects often require water to be pumped into the reservoir for storage, requiring electricity to run pumps (most electricity generation emits GHGs). In this way, development of new or expanded surface storage projects can work against efforts to mitigate the effects of climate change through GHG emission reduction efforts.

Conversely, depending on how individual surface storage projects are operated, they can provide substantial climate change mitigation benefits that in some cases more than offset emissions from construction. Surface storage reservoirs with hydroelectric generating capacity provide effective backup power supplies to be operated in tandem with intermittent renewable energy resources, such as wind and solar energy. Excess wind or solar energy can be used to run pumps to move water into offstream reservoirs, and water can be released from surface storage facilities to generate electricity when clouds obscure solar generation or when winds die down and reduce wind generation. Onstream reservoirs can produce substantial quantities of renewable, GHG-free hydroelectric energy.

Funding and Identifying Project Beneficiaries

Construction usually requires a substantial amount of money in a short time — millions to hundreds of millions of dollars. Included in the long-term capital outlay are planning costs, such as administrative, engineering, legal, financing, permitting, and mitigation costs. Some new-storage options, such as raising existing reservoirs, reoperating them, or constructing small local reservoirs, may require significantly less capital but may require local funding through revenue or general obligation bonds.

There are concerns related to how the beneficiaries will be determined, who will actually pay, and who will control a storage operation. One financing concept assumes that only the direct beneficiaries of a proposed storage project should pay for the construction and operation costs. However, many of the beneficiary groups do not have adequate financial resources to build large projects without outside financial assistance.

Another general financing concept relies on a large percentage of State and federal funding support to assist in the construction of new projects. With this method, the project beneficiaries would have a smaller, more affordable project cost component to fund. However, the process of obtaining funding approval from either federal or State government agencies generally requires substantially more time and justification documents. The challenge is to develop financial and operations agreements that have the best possibility for successful allocation of project costs corresponding directly to the beneficiaries and uses of a given project.

Impacts

New storage can affect environmental and human conditions and can create economic impacts for the surrounding community and flow impacts both upstream and downstream of diversions. New reservoirs may result in the loss of property tax revenue to local governments in the area where they are located, due to inundated developed land or land suitable for development, or may result in an increase of local property values by firming up a water supply. Regulatory and permitting requirements mean that surface storage investigations must consider potential impacts on streamflow regimes, potential adverse effects on designated wild and scenic rivers, potential water quality issues, potential changes in stream geomorphology, loss of fish and wildlife habitat, and risk of failure during seismic or operational events. Existing environmental laws require that these effects be addressed and potentially mitigated. Mitigation of environmental effects is normally accomplished through implementation strategies that avoid, minimize, rectify, reduce over time, or compensate for negative impacts. New surface storage projects are required to address impacts under the application of various laws, regulatory processes, and statutes, such as public trust doctrine, State dam safety standards, area-of-origin statutes, the California Environmental Quality Act, the National Environmental Policy Act, the Clean Water Act, and the California Endangered Species Act and federal Endangered Species Act.

Suitable Sites

Most of the best natural reservoir sites in California have already been developed, and environmental regulations and mitigation requirements impose significant constraints on development of new surface storage in California's mountainous areas. In some areas, the development of new offstream storage is a feasible alternative if the geographic terrain provides suitable locations. Another option that has received consideration in recent years is the rehabilitation and enlargement of existing reservoirs. This has the advantage of using an established reservoir site, but the feasibility and costs for rehabilitation of an older facility must be carefully evaluated.

Project Funding

The range of surface storage development options is generally more limited for smaller local agencies than for the State and federal governments, because limited agency funding and staff resources affect their capability to complete complex feasibility studies, design documents, environmental impact studies, and related project planning needs. These circumstances severely constrain the ability of local governments and agencies to finance and implement the projects necessary to sustain the local economy, preserve or restore riparian habitats, and provide water supplies for regional population growth. Traditionally, small local agencies have been unwilling to fund projects outside their service areas. However, recently, local partnerships through integrated regional water management plans (IRWMPs) have pooled resources and collaborated on local shared storage projects aimed at benefiting all regional participants.

Recommendations

1. Local agencies seeking to implement storage projects should develop a comprehensive methodology for analyzing all project benefits and costs. DWR should provide guidance, technical expertise, and planning process assistance to local agencies if requested.
2. Reservoir operators and stakeholders should continue to adaptively manage operations of existing facilities in response to increased understanding of system complexities and demands, as well as changes in natural and human considerations, such as social values, hydrology, and climate change.
3. DWR and other State, federal, and local resource management agencies should continue studies, research, and dialogue focused on a common set of tools that would help determine the full range of benefits and impacts, as well as the costs and complexities of surface storage projects.
4. Water resources scientists, engineers, and planners, including those at DWR, should recognize the potential long development time required for new surface storage in securing funding needed for continuity of planning, environmental studies, permitting, design, construction, and operation and maintenance.
5. Rehabilitation and possible enlargement of existing older dams and infrastructure should be given full consideration as an alternative to new reservoir storage.
6. As an alternative to new storage, agencies should consider the potential to develop water purchasing agreements to buy water from other agencies that own storage reservoirs with substantial water supplies.
7. Local agencies should investigate integrating existing surface storage with groundwater management or other water supply options (e.g., water use efficiency).
8. Local agencies should team with other regional agencies through the IRWMP process on new regional storage projects.
9. Surface storage can be the centerpiece of a comprehensive IRWMP offering multiple benefits and the flexibility to fully implement many other resource management strategies. Shared local or regional surface storage can enhance water user ability to implement conjunctive groundwater storage, integrate flood management practices, take full advantage of water transfers, assist in ecosystem restoration, and offer recreation benefits — all by augmenting consumptive water use.

Regional/Local Surface Storage in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions are not consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn't discussed in the rest of Update 2013), there is no need for this section to appear.]

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Chapter 15. Drinking Water Treatment and Distribution — Table of Contents

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Chapter 15. Drinking Water Treatment and Distribution

Providing a reliable supply of safe drinking water is the primary goal of public water systems in California. To achieve this goal, public water systems must develop and maintain adequate water treatment and distribution facilities. In addition, the reliability, quality, and safety of the raw water supply are critical to achieving this goal. In general, public water systems depend greatly on the work of other entities to help protect and maintain the quality of the raw water supply. Many agencies and organizations have a role in protecting water supplies in California. For example, the basin plans developed by the Regional Water Quality Control Boards recognize the importance of this goal and emphasize protecting water supplies —both groundwater and surface water.

A public water system is defined as a system for the provision of water for human consumption, through pipes or other constructed conveyances, which has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days of the year (Health and Safety Code, Section 116275[h]).

Public water systems (PWS) are divided into three principle classifications: community water systems (CWS), non-transient non-community (NTNC) water systems, and transient non-community (TNC) water systems. As the name indicates, CWS serve cities, towns, and other residential facilities occupied by year-round users. Examples include everything from apartment complexes served by their own well to systems serving California's largest cities. NTNC systems are PWS that are not CWS and provide water to the same non-residential users daily for at least 180 days of the year. Examples include schools, places of employment, and institutions. TNC systems are places that provide water for a population that mostly comes and goes. Examples include campgrounds, parks, ski resorts, rest stops, gas stations, and motels. Table 15-1 shows the number of public water systems in California by class. Community water systems serve approximately 36.6 million of the estimated 37.7 million people throughout the state, or 97 percent of the state's population. The remaining estimated 1.1 million people in the state (3 percent of the population) receive their drinking water from private wells serving their individual residences or from other sources. Virtually every Californian and visitor to the state will use drinking water from a regulated PWS through their work, while on vacation, or while traveling through the state. Figure 15-1 shows water system class by percent of total number of public water systems in California.

PLACEHOLDER Table 15-1 Public Water Systems in California by Class

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

PLACEHOLDER Figure 15-1 Public Water System Class by Percentage of Systems

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Under the California Safe Drinking Water Act (SDWA), the California Department of Public Health (CDPH) or CDPH Drinking Water Program has adopted regulations to ensure high quality drinking water is provided by public water systems at all times. In developing drinking water regulations and carrying out the public water system regulatory program, CDPH recognizes that healthy individuals and communities cannot exist without safe, reliable water supplies. These actions are necessary not only for drinking water, but also to meet basic sanitary and public safety needs.

Drinking water regulations mandated by the California SDWA apply to all public water systems, regardless of ownership. There are two basic water system ownership types - publicly owned and privately owned. Publicly owned systems include municipalities, special districts, and federal or state government systems. Privately owned systems include investor-owned utilities, mutual water companies, mobile home parks, water associations, and may include various commercial enterprises such as restaurants, hotels, resorts, employee housing, or other similar businesses that have their own water supply. While CDPH regulates all public water systems for all aspects that may affect water quality regardless of ownership, the California Public Utilities Commission (CPUC) regulates privately owned, for-profit systems serving communities for the purposes of establishing appropriate water rates. The CPUC regulates sole proprietorships, partnerships, and corporations that provide water service to the public for profit. Mutually owned systems and homeowners associations are exempt from CPUC oversight if they provide water only to their stockholders or members. In addition, systems serving privately owned mobile home parks are also exempt except that CPUC may conduct an investigation into water rate abuses when they receive complaints from residents. Table 15-2 provides a summary of the number and size of the CPUC-regulated water systems.

PLACEHOLDER Table 15-2 Number and Type of CPUC–Regulated Water Agencies

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

At the federal level, the U.S. Environmental Protection Agency (U.S. EPA) is responsible to ensure the implementation of the federal SDWA and related regulations. The State has primacy for the public water system regulatory program in California and works closely with U.S. EPA to implement the program. In addition, local primacy agencies (typically the county environmental health departments) are responsible for regulating many small public water systems (typically those serving less than 200 homes) in 32 of the 58 California counties. U.S. EPA directly provides regulatory oversight for tribal water systems.

Public water systems rely on groundwater, surface water, or a combination of both as their source of supply. Groundwater wells used for drinking water are constructed in a manner to intercept high quality groundwater. Therefore, many groundwater wells require little to no treatment. However, some groundwater wells are impacted by anthropogenic (manmade) and/or naturally occurring contaminants that require treatment to achieve the high level of quality mandated by state and federal regulations for a safe, reliable water supply. All surface water supplies used for drinking water must receive a high level of treatment to remove pathogens, sediment, and other contaminants before being suitable for consumption. Once the water is treated to drinking water standards, this high level of water quality must be maintained as the water passes through the distribution system to customer taps. Water treatment and distribution issues are discussed in detail later in this chapter. There is an increasing effort aimed at preventing pollution and matching water quality to water use. This is described in this volume in Chapter 18, Pollution Prevention and in Chapter 17, Matching Water Quality to Use.

The use of bottled water in the United States has been an increasing trend, however recently that trend appears to have flattened from 2007 through 2011. The Beverage Marketing Corporation and International Bottled Water Association report that U.S. consumption of bottled water was 29.2 gallons per person in 2011 and 29.0 gallons per capita in 2007. In 2005, California ranked No 1 in the nation for percent of the bottled water share (23.9 percent) and was ranked No. 3 behind Arizona and Louisiana for per capita consumption at 51.2 gallons (Donoho 2007). Some of the reasons that individuals choose bottled water include convenience, image, taste, and perceived health benefits. On the other hand, many consumers are becoming aware of the environmental impact associated with the production, transportation, and waste disposal of bottled water including the contributions to greenhouse gas emissions. While tap water and bottled water are regulated differently, both are generally safe, healthy choices. Tap water provided by a public water system yields public health and fire protection among its other advantages to a modern quality of life. Bottled water costs significantly more than tap water for the volume consumed in cooking and drinking.

Bottled water is regulated by the U.S. Food and Drug Administration under the 1938 Food, Drug, and Cosmetic Act (FD&C Act). California regulates bottled and vended water to a much greater degree than provided in the FD&C Act. The California Sherman Food, Drug, and Cosmetic Law is the basic statute that authorizes such regulation and is implemented by the CDPH Food and Drug Branch.

Drinking Water Treatment in California

Public Health

Water treatment includes processes that treat, blend, or condition the water supply of a public water system for the purpose of meeting primary and secondary drinking water standards. These processes include a wide range of facilities to treat surface water and groundwater. Common surface water treatment facilities include: basic chlorine disinfection, sedimentation basins, filtration, and more recent technical advances such as membrane filtration, ultraviolet light, and ozonation to meet pathogen removal and/or inactivation as well as disinfection requirements while controlling the formation of disinfection byproducts. Common facilities for groundwater sources that require treatment are chemical removal and/or blending facilities. Blending treatment is an acceptable practice for meeting chemical water quality standards and is a process of reducing the contaminant concentration in one water source by blending or dilution with water that has a lower contaminant concentration. Many water systems must also buffer or adjust the pH of the water to ensure that the delivered water is not corrosive in the distribution system and customers' piping. Fluoridation treatment, now commonly practiced in California, may be used to add fluoride to an optimal level that provides dental health benefits.

Widespread treatment of drinking water, especially disinfection, filtration, and fluoridation, was a great public health advancement of the 20th century. The 21st century promises to bring additional advances in water treatment technologies to improve the removal of contaminants, reduce cost the cost per gallon of treated water, improve water use efficiency (increase water recovery and reduce waste streams), and manage energy consumption. Water recovery, or recycling of water containing treatment process wastes (i.e., filter backwash water, filter rinse water) that would otherwise be disposed, begins with treatment of the recovered or recycled water so it may be blended with raw untreated water at the start of the treatment plant process. This enables a larger percentage of a water supply to be converted to potable water and concentrates the solids generated at the treatment plant. It is important for treatment processes in water-short areas to maximize the amount of a water supply that can be converted to potable water by reducing the amount of water that is discharged as waste.

California public water systems use an estimated 17,983 groundwater wells and surface water supplies to meet the water supply needs of consumers. Some of these sources need treatment to remove or inactivate harmful contaminants or to meet either aesthetic quality prior to consumption. These could include minerals, metals, chemicals from industry or agriculture, pathogens, and radiological constituents. Currently, there are an estimated 8,560 water treatment facilities in California. Most of these are disinfection facilities provided at sources, treated water storage tanks, or within the distribution system. The remaining systems provide more extensive treatment summarized in Table 15-3.

PLACEHOLDER Table 15-3 Treatment Plants on California Public Water System Sources

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Fluoridation

Fluoridation of community drinking water has been practiced in the United States for more than 60 years. It is accepted as a safe and effective public health practice for people of all ages. The previous five U.S. Surgeons General have recommended that communities fluoridate their water to prevent tooth decay, the major form of preventable dental disease in America. California's fluoridated drinking water act, Assembly Bill 733, became law in 1995 and required water systems with 10,000 or more service connections to fluoridate once money from an outside source is provided for both installation and operation and maintenance costs. CDPH is also responsible for identifying funds to purchase and install fluoridation equipment for public water systems.

During fluoridation treatment of public water system supplies, water systems adjust fluoride in drinking water to an optimal level shown to reduce the instances of tooth decay. Optimal fluoridation means that the water treatment facility and distribution system is closely managed to provide a consistent level of fluoride at the appropriate prophylactic level to reduce dental disease. Other water systems, that purchase water from a wholesale provider that fluoridates, provide variable fluoridation at levels up to the optimal level. The level of fluoride in these systems depends on many factors, including time of year, water demand, and the use of sources that may not have fluoridation treatment facilities. Additional information on water systems that provide fluoridated water is available at http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Fluoridation.aspx.

Regulation

Both the U.S. EPA and CDPH have ongoing programs for improving public health through new or more stringent drinking water regulations. These regulations include monitoring requirements, maximum contaminant levels (MCLs) in the water provided to the customer, multi-barrier treatment requirements, permitting requirements, public notification, and more. These regulations include specific MCLs for constituents of health concern that are present in drinking water sources. In California, new drinking water standards—the MCLs—are adopted only after development of a Public Health Goal (PHG), which is the level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the Office of Environmental Health Hazards Assessment, an agency under the California Environmental Protection Agency (Cal EPA). MCLs take into account not only chemicals' health risks, but also factors such as their detectability and treatability, as well as costs of treatment. The California Health and Safety Code requires CDPH to establish a contaminant's MCL at a level as close to its PHG as is technically and economically feasible, placing primary emphasis on the protection of public health.

In some cases, California adopted MCLs in advance of the federal adoption of an MCL. For example, CDPH adopted a perchlorate MCL of 6 µg/L in 2007. This MCL is based primarily on potential adverse effects on the thyroid. In 2008, the U.S. EPA indicated that it did not intend to adopt an MCL for perchlorate. However, in 2011 the U.S. EPA reversed its earlier decision and now plans to propose a formal rule for perchlorate (U.S. EPA 2011). In September 2012, U.S. EPA posted a Federal Register notice of a public meeting regarding their intent to regulate perchlorate levels in drinking water through adoption of an MCL and anticipates that a draft rule will be available for public comment in 2013.

CDPH is currently in the regulation process to establish an MCL for chromium-6. On July 1, 2011, Cal EPA's Office of Environmental Health Hazard Assessment completed the setting of a PHG for chromium-6 at a concentration of 0.02 µg/l, a necessary prerequisite to adopt an MCL. CDPH is required by law to establish MCLs that are as close to a PHG as are technically and economically feasible. CDPH anticipates that a draft MCL for chromium-6 will be ready for public comment by July 2013. Depending on public comments, the regulatory package for chromium-6 should be formally adopted sometime between July 2014 and July 2015.

In addition, if the adoption of a specific MCL is not practical, U.S. EPA and CDPH have adopted specific treatment performance standards that essentially take the place of an MCL. An example of this is in the various rules for surface water treatment that are intended to provide protection against *Giardia* and *Cryptosporidium*, two microbial contaminants found in surface waters where direct testing is impractical, costly, or lacks the level of reliability necessary in setting an MCL.

New Technology

New or innovative treatment technologies are often developed to address new or more stringent drinking water standards, improve the contaminant removal efficiency, reduce treatment plant footprint, reduce energy consumption, or reduce/eliminate waste streams from the treatment process. Innovative environmental technologies hold the promise of being more effective than traditional methods and can address today's far more complex environmental problems. Technologies increasingly used in California as a result of new regulations include:

- Ultraviolet (UV) disinfection treatment to comply with disinfection byproducts under the Stage 2 Disinfection Byproducts Rule and requirements for the treatment of surface waters under the Long Term 2 Enhanced Surface Water Treatment Rule.
- Arsenic removal technologies including adsorptive (disposable) media to increase affordability of small water system compliance with the arsenic MCL.
- Membrane filtration to comply with requirements of the Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules.
- Biological treatment in the form of fixed bed, fluidized bed, and membrane bioreactors to treat for perchlorate and now being demonstrated for nitrate and other contaminants.

As a result of both increases in demand and the relative scarcity of new water supplies, many water providers are now shifting toward treating sources formerly considered unsuitable for domestic use.

Treatment processes such as reverse osmosis are used to desalt brackish shallow groundwater for potable uses and are discussed in greater detail in Chapter 10, Desalination – Brackish Water and Seawater in this volume.

Drinking Water Distribution in California

Treated and/or conditioned water that meets drinking water standards is considered to be "finished water", suitable for distribution to consumers for all potable water uses. Water distribution systems consist of pipes, storage tanks, pumps, and other physical features that deliver water from the source or the water treatment plant to the customer's connection. Even high quality drinking water is subject to degradation as it moves through the distribution system to the tap. For example, contaminants can enter the distribution system via backflow from a cross-connection, permeation and leaching, during water main repair or replacement activities, and contamination via finished water storage facilities. Within the distribution system, water quality may deteriorate as a result of microbial growth and biofilm, nitrification, corrosion, water age, effects of treatment on nutrient availability contributing to microbial growth and biofilm, and sediments and scale within the distribution system (U.S EPA 2006).

CDPH has established laws and regulations for the design, construction, operation, and maintenance of distribution systems primarily through the California Waterworks Standards (California Department of Public Health 2008a). Regulations mandate monitoring distribution system water quality for coliform bacteria, chlorine residual, lead, copper, physical water quality parameters, and disinfection byproducts. California has also adopted cross-connection control and backflow prevention regulations to protect water quality within a water distribution system.

In 2000, a federal advisory committee working to develop more stringent U.S. EPA regulations for disinfection byproducts and microbial contamination noted the following as part of its key considerations to develop further regulations in these areas:

- Finished water storage and distribution systems may have an impact on water quality and may pose risks to public health.
- Cross-connections and backflow in distribution systems represent a significant public health risk.
- Water quality problems can be related to infrastructure problems and the aging of distribution systems may increase risks of infrastructure problems.
- Distribution systems are highly complex and there is a significant need for additional information and analysis on the nature and magnitude of risk associated with them.

The maintenance of water quality within the distribution system has received considerable attention in recent years, especially as systems have modified treatment methods. Changes to the methods and levels of disinfectants can create the potential for reduced control of microbial contaminants that may be present in the distribution system.

Water utilities are also constantly making improvements to their distribution systems, including increasing the reliability of their water supply. One example is the installation of emergency water interties between neighboring water utilities. These interties provide a backup source, with the neighboring water system, in case of an outage due to an unforeseen emergency or a potential disaster.

The intertie also allows a water utility to shut down a part of its system to do necessary maintenance without interrupting service to customers.

For example, a number of Bay Area water systems have constructed emergency interties with neighboring water systems. There is an emergency intertie between the East Bay Municipal Utility District (EBMUD), the City of Hayward, and the San Francisco Public Utilities Commission (SFPUC) to supply treated water among the three water systems and is intended to be used during planned outages, for needed maintenance, and to avoid service interruptions. EBMUD has two small interties, each able to carry 4 million gallons per day, with the City of Hayward which adjoins its service area. SFPUC, the agency in charge of the Hetch Hetchy water used by many Bay Area water districts and residents, has also constructed an intertie with the Santa Clara Valley Water Agency and has been considering constructing another intertie. These interties may also play a role in the security of the water distribution system by creating a backup source should a terrorist act or disaster disrupt the source of supply from any single water provider.

In other cases, interties can provide untreated water between utilities in an emergency. For example, Contra Costa Water District (CCWD), whose service area is crossed by EBMUD Mokelumne pipeline, has an intertie which can be used to transfer untreated water between EBMUD and CCWD in an emergency.

Interties are one of the strategies for improving water supply reliability and quality which were recommended by the CALFED August 28, 2000 Record of Decision.

Potential Benefits

Improved water quality can directly improve the health of Californians, thereby improving the state’s standard of living and reducing the burden and costs on the state’s healthcare system.

Since 1989, a number of rules have been adopted by U.S. EPA and CDPH that are aimed at controlling both microbial pathogens and disinfection byproducts. The first of these rules were the Surface Water Treatment Rule (1989) and the Total Coliform Rule (1989). Both rules intended to reduce the risk to consumer of both viral and microbial pathogens in drinking water. As the regulatory community became more aware of the risks posed by organisms such as *Giardia*, *Cryptosporidium*, and certain enteric viruses present in surface water supplies, rules were adopted to address these risks and increase the degree of protection for consumers. These rules included:

- Interim Enhanced Surface Water Treatment Rule (1998).
- Filter Backwash Rule (2001).
- Long Term 1 Enhanced Surface Water Treatment Rule (2002).
- Long Term 2 Enhanced Surface Water Treatment Rule (2005).

Concurrently, rules were adopted to improve the disinfection process while at the same time providing protection against two groups of disinfection byproducts, trihalomethanes (TTHM) and haloacetic acids (HAA5). The following disinfection byproduct rules were adopted:

- Stage 1 Disinfection Byproducts Rule (1998).
- Stage 2 Disinfection Byproducts Rule (2006).

In addition to the surface water rules, U.S. EPA adopted the Groundwater Rule (2006) to increase the level of protection primarily from enteric viruses.

The perchlorate MCL and the arsenic MCL reduce the permissible level of these contaminants and result in direct benefits. Perchlorate exposure is a public health concern because it interferes with the thyroid gland's ability to produce hormones. In the very young, hormones are needed for normal prenatal and postnatal growth and development, particularly for normal brain development. Therefore, a reduction in thyroid hormones is a serious concern. In adults, thyroid hormones are needed for normal body metabolism. About 515,000 people in California will avoid exposure to perchlorate at levels above the MCL annually as a direct result of the perchlorate regulation (California Department of Public Health 2007). The arsenic MCL of 10 ug/L will result in an exposure reduction for more than 790,000 people and a theoretical reduction of 57 lung and bladder cancer cases per year in California (California Department of Public Health 2004).

Adequate operation and maintenance of the distribution system network will reduce delivery problems (main or tank ruptures, water outages) and ensure delivery of high quality water. In California, operators of drinking water distribution systems must be certified at the appropriate level depending on the size and complexity of the distribution system. This certification requirement helps to ensure a competent level of operation of distribution systems.

Similarly for water treatment facilities, proper operation and maintenance is essential for achieving optimum water treatment plant performance. In California, operators of drinking water treatment facilities must be certified at the appropriate level depending on the size and complexity of the treatment facilities.

Water fluoridation ranks as one of ten great public health achievements of the 20th century according to the U.S. Surgeon General in 2000. Fluoridation of public water supplies targets the group which would benefit the most from its addition, namely infants and children under 12, by decreasing cavities and improving dental health. Studies have shown unequivocally that fluoridation, at the optimal concentration, reduces the incidence of dental caries by 50-70 percent. It has also been demonstrated that carries will increase if water fluoridation is discontinued in a community for an extended period. One example is what happened in Antigo, Wisconsin. Antigo started fluoridating its community water supplies in 1949 and discontinued it in 1960. Five and one-half years later, second graders had more than 200 percent more tooth decay, fourth graders had 70 percent more, and sixth graders had 91 percent more tooth decay than children of the same age in 1960 (California Department of Public Health Community Water Fluoridation Program 2009).

Potential Costs

The cost of providing drinking water in compliance with all drinking water standards is steadily increasing due to increasing costs for energy and materials and increasing regulations requiring higher levels of treatment. Water bills reflect the costs of pumping, treating, and delivery of water as well as the operation and maintenance of the system, water quality testing, and debt repayment. Water treatment costs may include the cost of chemicals, energy, and operation and maintenance of the treatment facilities. Drinking water treatment costs will vary widely from plant to plant. Many different factors can affect the cost of water treatment, including the choice of which water treatment technology to use.

Table 15-4 summarizes the past and future estimated costs of treated full-service water provided by the Metropolitan Water District of Southern California (MWD), which treats a blend of surface water from the Colorado River and the California Aqueduct. The table shows an increase of approximately 65% from 2007 to 2012 in the cost to provide treated water in an area serving a large rate base. The additional cost reflects improvements to the treatment provided, increased cost for chemicals and energy, and reduced availability of new water supplies. The primary cost factors causing the rate increase included increased conservation efforts, the quagga mussel control program, litigation, and the higher cost for State Water Project deliveries. MWD may not capture the true cost of service with these rates and must cover some costs through the use of reserves.

PLACEHOLDER Table 15-4 Metropolitan Water District of Southern California Treated Water Rate History

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

The increase in cost to provide safe drinking water for smaller systems may be significantly greater on a per capita basis. These systems lack the economy of scale necessary to achieve savings in their day-to-day operations. In addition, most small systems have not set up any assets management plan or created a capital improvement account as a means to fund infrastructure replacement.

Per household costs for compliance with new regulations for small water systems can be more than four-fold higher than those for medium-to-large water systems (U.S. EPA 2006). Where substantial areas are impacted by contamination, such as the nitrate contamination in the Tulare Lake basin and Salinas Valley, the cost to consumers can be significant. According to a recent UC Davis study titled Addressing Nitrates in California's Drinking Water – Technical Report 7: Alternative Water Supply Options (Honeycutt K, Canada HE, Jenkins, MW, Lund JR 2012), about 2.4 million people receiving groundwater supplies from community water systems and state small water systems are potentially impacted by nitrate in the Tulare Lake basin and Salinas Valley study areas. In addition, about 245,490 persons in these areas obtain water from unregulated private water supplies that may also be subject to nitrate contamination. According to the UC Davis study, the estimated cost per person to provide safe water (water that meets nitrate standards) is estimated to be between $80 and $142 per year. For a typical public water system customer, this cost represents an estimated increase in the monthly water bill from $23 to $42/month based on $80 to $142/yr. x 3.5 persons per household.

The most prevalent groundwater contaminant is arsenic, a naturally occurring contaminant, affecting an estimated 287 community drinking water system statewide (State Water Resources Control Board 2012). The average annual cost per household to comply with the arsenic MCL is estimated to range from $140 to $1,870 per residence depending on the size of the water system (California Department of Public Health 2008b). These costs are in addition to current costs for drinking water.

Up to one-third of the operations and maintenance costs for some water utilities are energy related, including energy used for water treatment and pumping. One factor in water-related energy consumption is using new technologies that are more energy intensive than most previous treatment technologies e.g., UV treatment and high pressure membranes.

Desalination will play an increasing role in California's water supply, both for brackish groundwater desalination and seawater desalination. Historically, the high cost and energy requirements of desalination had confined its use to places where energy is inexpensive and freshwater is scarce. Recent advances in technology, especially improvements in membranes, have made desalination a realistic water supply option. The cost of desalinating seawater is now competitive with other alternatives in some locations and for some high-valued uses. However, although process costs have been reduced due to the newer membranes that allow for lower energy consumption, the total costs of desalination, including the costs of planning, permitting, and waste salt brine concentrate management remain relatively high, both in absolute terms and in comparison with the costs of other alternatives (National Resource Council 2008). Since development of other traditional sources of supply is limited and may require substantial capital investment, such as new storage or canal systems, the expanded development of brackish water and seawater desalination may become more cost competitive.

The condition of infrastructure is a growing concern in California and throughout the country. In the *Report Card for America's Infrastructure*, the American Society of Civil Engineers gave drinking water infrastructure across the country a D-minus. The U.S. EPA conducted a Drinking Water Infrastructure Needs Survey and Assessment in 1995, 1999, 2003, 2007, and 2011 (results are still being compiled by U.S. EPA). The 2007 survey shows a total investment need of $334.8 billion over the next 20 years nationwide. It identified a total investment need of $39.0 billion for California. This is more than 11 percent of the national need. The majority of the California need was for transmission and distribution systems (59%, or $22.98 billion). The second highest need category was for treatment (20%, or $7.5 billion), followed by water storage (15%, or $5.7 billion), and water source (6.4% or $2.5 billion) (All amounts are in January 2007 dollars). This does not include the infrastructure needs of tribal water systems that are regulated directly by U.S. EPA as tribal nations. See the following link for information about these systems: http://water.epa.gov/infrastructure/drinkingwater/dwns/upload/2009_03_26_needssurvey_2007_report_needssurvey_2007.pdf . California's investment needs may not include all cost associated with changes in the Colorado River water resources, recent or evolving drought issues, or changes to groundwater basins.

Funding for drinking water projects on tribal lands is provided by the federal government as part of the Drinking Water Infrastructure Grants: Tribal Set-aside Program, which was established by the federal Safe Drinking Water Act reauthorization of 1996. The program allows the U.S. EPA to award federal grants for infrastructure improvements for public drinking water systems that serve tribes.

Major Implementation Issues

Based on a review of issues discussed within the water supply industry and regulatory agencies, the following topics represent some of the most significant challenges for public water suppliers and the regulatory agencies today.

Deteriorating Infrastructure

With the aging of the nation's infrastructure and the growing investment needed to replace deteriorated facilities, the water industry has a significant challenge to sustain and advance its achievements in protecting public health and the environment (Grumbles 2007). During the last several decades, the public investment has been toward expanding and upgrading service levels, such as providing higher levels of treatment.

New solutions are needed for critical drinking water investments over the next two decades. Many utilities are moving to the concept of asset management to better manage and maintain their water facilities and infrastructure (Cromwell et al. 2007) for greater operational efficiency and effective use of limited funds. However, addressing the replacement of deteriorating infrastructure will add to the cost of water.

Asset management alone will not fix the basic problem. Particularly in smaller systems, inadequate funding for capital improvement plans for infrastructure replacement has created a serious problem. From the post-war period of the late 1940s and into the early 1980s, there was a proliferation of small community water systems located in rural areas and remote from the cities. In the past, such systems could often fund major maintenance and needed infrastructure replacement with informal assessments from the rate payers. However, the magnitude of the current infrastructure needs makes it very difficult to finance without creating an inordinate burden on rate payers.

CDPH has funding 'set-asides' from the Drinking Water State Revolving Fund (DWSRF) program to provide technical assistance to small water system operators and managers for technical, managerial, and financial areas. Additional funding would allow the expansion of this program into more detailed areas of asset management and rate setting.

Source Water Protection

There is an increasing need to protect source water quality as the first critical barrier in the multiple barrier approach to provide safe drinking water. A key issue is the increasing difficulty of protecting source water quality as the state population increases which results in increased wastewater discharge and urban runoff into surface water supplies. Another major issue is that some drinking water contaminants (organic carbon, nutrients, and pathogens such as *Giardia* and *Cryptosporidium*) are not currently regulated by the Regional Water Quality Control Boards in basin plans. Thus, there are generally no requirements for dischargers to control these contaminants.

Inadequate Financial Assistance to Address Both Water Treatment and Infrastructure Issues of Public Water Systems

The four major funding programs for California public water systems are DWSRF, Proposition 50, Proposition 84, and the American Recovery and Reinvestment Act of 2009 (ARRA). Combined, these programs have provided more than $1.87 billion to 441 public water systems to solve health risk problems and Safe Drinking Water Act violations, resulting in an overall risk reduction for consumers. However, this funding has not been adequate to address all of California's identified needs. The combined project priority list for these funding programs includes more than 4,000 projects, many of which have been on the list since its inception in 1997 and have not received funding. The estimated value of unfunded need on the combined project priority list exceeds $12 billion is shown in Table 15-5.

PLACEHOLDER Table 15-5 California Department of Public Health Summary of Funded and Unfunded Projects

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

The CDPH Drinking Water Program administers multiple funding programs to assist water systems to achieve and maintain compliance with safe drinking water standards. These programs use federal funds and state funds to address the highest priorities of the total infrastructure need.

Safe Drinking Water State Revolving Fund

The largest funding program CDPH administers is the Safe Drinking Water State Revolving Fund (SDWSRF). The U.S. EPA provides SDWSRF funds to states in the form of annual Capitalization Grants. States, in turn, provide low interest rate loans and other assistance to public water systems for infrastructure improvements. In order to receive a federal SDWSRF Capitalization Grant, states must have statutory authority for the program and must provide a state match equal to 20 percent of each annual Capitalization Grant. Pursuant to state statutes (Health and Safety Code, Division 104, Part 12, Chapter 4.5 commencing with Section 116760, Safe Drinking Water State Revolving Fund Law of 1997), CDPH is authorized to receive the federal Capitalization Grants and administer the SDWSRF program in California. California's SDWSRF program began in 1998 and issued its first loans in 1999. California's current share of the national SDWSRF is 9.35% (see Table 15-6) and it is the highest allocation of all states.

PLACEHOLDER Table 15-6 California Safe Drinking Water State Revolving Fund: Capitalization Grants from the U.S. EPA

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Total SDWSRF funding provided to public water systems in executed loans and grants to date is more than $1.3 billion. Approximately 80 percent of these funds are distributed by CDPH as subsidized interest rate loans to public water systems serving disadvantaged communities. The remainder is distributed in the form of grants to disadvantaged communities. Water systems determined to serve a disadvantaged community receive a zero percent interest rate loan and may receive grant funding. Disadvantaged communities are communities with a median household income (MHI) less than or equal to 80% of the statewide MHI and may receive grant funding up to 80% of the project costs based on affordability criteria. Severely disadvantaged communities are communities with a MHI less than or equal to 60% of the statewide MHI and may receive grant funding up to 100% of the project costs based on affordability criteria.

The majority of the SDWSRF funding is subsidized, low interest rate and zero interest rate loans that typically have a 20-year repayment term. All loans are secured, however the security varies and is most often provided by user water rates, charges, and/or surcharges. As the outstanding loans are repaid, they generate a steady repayment stream that currently exceeds $40 million per year. In accordance with state and federal SDWSRF laws, the funds from the repayment stream are added to the SDWSRF fund and can be utilized in the same manner.

SDWSRF Funding Priority

In accordance with federal requirements and state law, CDPH establishes the priority for SDWSRF funding based on the risk to public health. Each pre-application submitted for funding is evaluated and if eligible for funding is assigned a category, based on the problem to be addressed. Highest categories are problems associated with bacteriological pathogens, followed by nitrate, and then other chemicals that exceed primary (health-based) drinking water standards.

After the appropriate funding category is determined, CDPH further prioritizes projects based on bonus points. Bonus points are used to rank projects within a category. The addition of bonus points will not move a project from one category to another. To the extent feasible, when a group of systems is invited to complete the application process for SDWSRF funding, all the systems within that category seeking funding that year are invited to apply. Bonus points are assigned based on affordability, consolidation, type of water system, and population.

CDPH factors in affordability by comparing the MHI of the community served by the proposed project to the statewide MHI level. Communities that are below the statewide average MHI level receive additional ranking consideration. This gives poorer communities a higher ranking within a category than communities with higher income levels.

For purposes of ranking projects within a category, any project that includes consolidation of separate existing water systems will receive additional ranking points. Consolidation ranking points support projects that will provide reliability, efficiency, and economy of scale that can be achieved with larger water systems while discouraging the proliferation of numerous separate small systems that have inherent inefficiencies and limitations.

The type of water system is considered in prioritizing because there is a relatively higher health risk associated with persons who drink the same water each day over a period of time, known as accumulated exposure. Thus, community and non-transient non-community water systems are ranked above transient non-community systems within a category and with the same bonus ranking points.

All projects within a category that have the same number of ranking points and are the same type of system are ranked in ascending order based on the population served by the water system. Smaller populations are ranked above higher populations.

CDPH combines all these factors to develop a Project Priority List (PPL) each year. CDPH then invites projects for funding from the PPL. Recently, Congress has required states to commit 20% of the SDWSRF funds to "green projects" such as water or energy efficiency, green infrastructure, or other environmentally innovative activities. CDPH has awarded a portion of the funding to install water meters in disadvantaged communities.

American Recovery and Reinvestment Act

The American Recovery and Reinvestment Act was signed by President Obama on February 17, 2009. ARRA allocated $2 billion nationally for safe drinking water infrastructure improvements. California's share of these funds is $159 million and is administered by CDPH through its existing SDWSRF program. The ARRA funds were a one-time opportunity and did not require state matching funds.

CDPH issued funding agreements totaling $149 million to 51 projects statewide. These 51 projects are distributed among 47 community drinking water systems. The funds were committed to drinking water infrastructure projects that were identified as "ready to proceed." All funding agreements were issued by

December 2009 and all projects were under construction by February 2010. The ARRA-funded projects are in different stages of construction and all must be completed by June 30, 2013.

Proposition 50

Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Water Code Section 79500, et seq.) was passed by California voters in the November 2002 general election. CDPH is responsible for portions of the Act that deal with water security, safe drinking water, and treatment technology. This approved bond measure allocated $485 million to CDPH to address drinking water quality issues in California. Proposition 50 authorizes up to 5 percent of the funding for CDPH to administer the funding programs listed below. In addition, 3.5 percent must be allocated for bond costs. Under Proposition 50, CDPH is also responsible for multiple funding programs described below.

Chapter 3, Water Security

Water Code Section 79520 provides $50 million to CDPH to protect state, local, and regional drinking water systems from terrorist attacks or deliberate acts of destruction or degradation. These funds may be used for

- Monitoring and early warning systems.
- Fencing.
- Protective structures.
- Contamination treatment facilities.
- Emergency interconnections.
- Communications systems.
- Other projects designed to
    - Prevent damage to water treatment, distribution, and supply facilities.
    - Prevent disruption of drinking water deliveries.
    - Protect drinking water supplies from intentional contamination.

CDPH developed criteria that prioritized Chapter 3 funding to water systems to construct emergency interties with adjacent water systems. Emergency intertie connections ensure there is an alternate connection to a water system if there is a disruption in water supplies during emergencies, such as natural catastrophes or terrorist attacks. This provides additional assurance of continuous water supplies to the largest populations.

Chapter 4, Safe Drinking Water

Water Code Section 79530 provides funding to CDPH for grants for public water system infrastructure improvements and related actions to achieve safe drinking water standards.

Section 79350(a) (Chapter 4a) provides $70 million for grants to small community water systems (less than or equal to 1,000 service connections or less than or equal to 3,300 persons) to upgrade monitoring, treatment, or distribution infrastructure. It also provides grants for community water quality monitoring equipment, drinking water source protection, and treatment facilities necessary to meet disinfection byproduct drinking water standards. CDPH developed criteria that prioritized Chapter 4a funding to water systems based on public health risk, using the SDWSRF categories as well as other criteria specific to the funding section. In addition, the criteria give priority to disadvantaged communities within each category.

Section 79350(b) (Chapter 4b) provides $260 million for grants to Southern California water agencies to assist in meeting California's commitment to reduce Colorado River water use to 4.4 million acre-feet per year. CDPH developed criteria that prioritized Chapter 4b funding to water systems in accordance with the bond language. Projects are assigned points based on three ranking criteria and a cumulative score is determined for each project. The projects are then ranked by that score from lowest to highest. Criterion 1 ranks projects by Proposition 50/AB 1747 categories and by water system population (from highest to lowest) within a category. Criterion 2 ranks projects by reduction of the annual volume of Colorado River water demand. Criterion 3 ranks projects by the cost per volume of the reduced demand.

Proposition 84

Proposition 84, the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Act of 2006 (Public Resources Code Section 75001, et seq.) was passed by California voters in the November 2006 general election. This approved bond measure allocated $300 million to CDPH to address drinking water and other water quality issues in California. Proposition 84 authorizes up to 5 percent of the funding for CDPH to administer the funding programs. In addition, 3.5 percent must be allocated for bond costs. Within Proposition 84, CDPH is responsible for multiple funding programs listed below.

- Section 75021 provides $10 million for grants and direct expenditures for emergency and urgent actions to ensure safe drinking water supplies. CDPH developed criteria to determine the eligibility of Emergency Grant projects. All requests that meet the eligibility criteria are funded until the funds are exhausted. Factors that CDPH considers include:
    - Type of contaminant(s).
    - Degree of contamination.
    - Whether the health hazard is acute (immediate) or chronic (long-term).
    - Length of time to which consumers have been or will be exposed.
    - Any actual or suspected illnesses.
    - Any actions taken by the local Health Officer or the local Director of Environmental Health.
    - Other funds to resolve the public health threat or emergency.
    - Duration and extent of a water outage due to an emergency.
    - Duration and extent of loss of power due to an emergency.
- Section 75022 provides $180 million in grants for small community drinking water system infrastructure improvements for chemical and nitrate contaminants and related actions to meet safe drinking water standards. $7.5 million is allocated, pursuant to 2011-2012 Budget Act, to projects in the City of Santa Ana and the City of Maywood.

  CDPH developed criteria that prioritize eligible projects in accordance with the bond language and subsequent legislation. Projects were scored by points based on:
    - Regulatory status of the principal contaminant to be addressed.
    - Health risk associated with the principal contaminant to be addressed.
    - Number of contaminants in the project's drinking water supply that exceed a primary drinking water standard.
    - Median household income of the applicant water system.

  - Project includes consolidation.
  - Project is part of a regional project.
- Section 75025 provides $60 million for immediate projects needed to protect public health by preventing or reducing the contamination of groundwater that serves as a major source of drinking water for a community. $2 million of the funding is allocated, pursuant to SB X2 1, to the State Water Resources Control Board to develop pilot projects in the Tulare Lake basin and the Salinas Valley that focus on nitrate contamination.

CDPH developed criteria that prioritize eligible projects in accordance with the bond language and subsequent legislation. Projects were scored by points which are based on the regulatory status of the principal contaminant to be addressed; the health risk associated with the principal contaminant to be addressed; the number of contaminants in the project's drinking water supply that exceed a primary drinking water standard; the median household income of the applicant water system; whether the project includes consolidation; and whether the proposed project is part of a regional project.

Regionalization/Consolidation

One way to improve the economy of scale, which results in the potential for many benefits including lower costs, is to increase regionalization of water supply systems. This can be achieved by physical interconnections between water systems or managerial coordination among utilities. CDPH has established a requirement for evaluating consolidation as part of every project funded under the available financial assistance programs. To address deteriorating infrastructure successfully for the hundreds of smaller public water systems in California, regionalization and consolidation may be necessary on a larger scale. It is not cost-effective for a small system to replace aging and deteriorated sources, treatment plants, and distribution systems fully. However, with a larger rate base to spread costs across, the economies of scale improve for consolidated systems. Managerial consolidation of water districts, even where the boundaries are not contiguous, can provide great savings to the consumers by sharing the costs of oversight and management of the systems, thus freeing up funds for system upgrades. Box 15-1 describes a regional consolidation project in the planning stages.

PLACEHOLDER Box 15-1 Rosamond Community Services District Regional Consolidation Project

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Disadvantaged Communities/Environmental Justice

There has been heightened interest in environmental justice issues as a result of nitrate contamination problems in public water systems, particularly those in agricultural areas such as the Central Valley. It is the role of the federal government to ensure that, in the development and implementation of new regulations, disadvantaged communities are protected at levels afforded to other demographic communities. Presidential Executive Order 12898 establishes a federal policy for incorporating environmental justice into federal agencies' missions by directing them to identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations.

Each of the three major water system funding programs implemented by CDPH provides some special financing for water systems that serve areas with relatively low median household income. For example, the SDWSRF can provide grant funds and zero-interest loans to water systems serving a community with a low MHI as stated earlier. Proposition 50 funding has a target goal to provide 25 percent of the funding to low-MHI communities. A significant portion of the Proposition 84 funds allocated to drinking water are specifically targeted at small disadvantaged communities with contamination problems. Funding from both Propositions 50 and 84 is limited due to the one-time allocation specified for drinking water.

Impact of Climate Change

Climate change projections include warmer air temperatures, diminishing snowpack, precipitation extremes and storm intensity, prolonged droughts, and sea level rise. These anticipated changes could affect water quality in regions that are already experiencing difficulty meeting current water demands.

Earlier snowmelt and more intense episodes of precipitation with increased flood peaks may lead to more erosion, resulting in increased turbidity and concentrated pulses of pollutants in source waters. Increased flooding may lead to sewage overflows, resulting in higher pathogen loading in source waters. These potential changes could result in challenges for surface water treatment plants and may require additional monitoring to quantify changes in source water quality and to meet post-treatment drinking water standards.

Increased water temperatures and reduced reservoir levels may result in more prevalent eutrophic conditions, increasing the frequency and duration of algal blooms. Higher water temperatures can also accelerate some biological and chemical processes, such as increasing growth of algae and microorganisms, depletion of dissolved oxygen, and various impacts to water treatment processes. Higher sea levels as a result of climate change could impact coastal groundwater basins by making protection of groundwater from seawater intrusion more difficult.

Adaptation

Increasing demand on limited and valuable water resources available in California will compound any climate change impact. The continued growth in the state will continue to stress the availability of the freshwater resources needed for domestic, agricultural, and industrial uses. California coastal water providers have begun evaluating and employing desalination of seawater as an additional drinking water supply. Desalinated seawater, although more expensive to develop due to the high energy requirements and planning and permitting costs, has been identified as a reliable drought-proof supply.

Regionalization of water supply systems as an adaptation strategy will also help counter the effects of climate change by adding operational flexibility during periods of drought or flooding. Investments in drinking water facilities and conveyance systems will add efficiency and lead to enhanced sustainability in the future. Adaptation to climate change to provide adequate drinking water will likely require specific regional strategies described in this chapter that focus on conservation, sustainability, and operational flexibility.

Mitigation

Demand for drinking water treatment and distribution will continue to increase as climate change has major impacts on water quality and availability of the freshwater resources used for drinking water.

Adverse impacts on climate change related to increasing greenhouse gas emissions could result from energy uses in 1) drinking water treatment and distribution systems, 2) bottled water production including related transportation and waste disposal, and 3) treatment of new sources of drinking water from low quality groundwater and recycled wastewater. However, improving water and energy efficiency from management strategies described in this chapter could have benefits that reduce energy uses and greenhouse gas emissions as part of climate change mitigation including:

- Promoting opportunities to use more tap water and less bottled water to reduce related energy and greenhouse gas emissions.
- Conducting audits for water and energy efficiency in drinking water treatment and distribution systems.
- Providing operational efficiency and improving aging infrastructure to control water losses for water and energy saving.
- Developing programs and applying new technologies to reduce energy use in both water treatment plants and for new sources of drinking water such as low quality groundwater and recycled wastewater.
- Developing energy efficiency standards for drinking water treatment and distribution systems.
- Coordinating with water use efficiency programs and using best management practices to save water and energy such as utility leak detection, water conservation, and water efficiency pricing and incentives for installing water efficient appliances and landscaping.

Water Use Efficiency

The efficient use of water is regarded as a viable complement, and in some instances a substitute, to investments in long-term water supplies and infrastructure. Water use efficiency is a concept to maximize the use of water or minimize its waste. Water use efficiency will continue to be a key element of addressing reduced water availability and is regarded as a major step to take before turning to more costly water sources such as desalinated seawater. Water efficiency programs and practices may include utility leak detection, water conservation programs, water efficiency pricing and incentives for installing water efficient appliances and landscaping, as well as improvements in water recovery as part of water treatment plants (e.g., recycling water used in treatment plant processes for backwash).

An important aspect of strongly encouraging water conservation is the ability of the water utility to establish an escalating metered rate based on the volume of water used. This promotes full cost recovery, conservation, or efficiency pricing. Since 1992, California law has required urban water suppliers (those serving more than 3,000 connections or delivering more than 3,000 af of water per year) to install a water meter on new connections. More recently, AB 2572 established the requirement for retrofitting water meters on pre-existing connections and charging customers for water based on the actual volume of water used. Neither of these laws addresses smaller water systems that do not meet the definition of an urban water supplier.

However, many larger water agencies have already taken advantage of conservation programs to reduce the need for new water supplies. The Los Angeles Department of Water and Power (LADWP) has shown success in conservation where water use today is the same as it was 25 years ago, despite a population increase of nearly 1 million people (City of Los Angeles Department of Water and Power 2008). Obtaining additional conservation increases will be more difficult and may result in higher costs to achieve.

To address water losses or unaccounted water, water utilities conduct audits to identify water main leaks, unmetered water use for parks and recreation consumption, water theft, and inaccurate meters. Deteriorated and aging infrastructure can play an important role in water losses which contributes to significant water leakage and a high rate of water main breaks. Nationally, there has been reported water losses by utilities of between 10% to nearly 50% of the water produced. Due to the continued aging of distribution infrastructures that are at or near the end of their useful life, water losses due to water main leaks can be expected to remain a significant and potentially increasing barrier to California's efforts to conserve water. Both the Safe Drinking Water State Revolving Fund program and the American Recover and Reinvestment Act administered by CDPH, provide funding to drinking water systems for water meter installation. Water meters are an important tool to measure water loses in the distribution system.

Maintaining a Trained Workforce

California requires operators of water treatment plants and distribution systems to receive certification to perform these duties. This certification is designed to ensure that operators have adequate knowledge, experience, and training to operate these facilities properly. Due to the increased complexity of water system facilities, the importance of properly trained and certified operators is increasing.

Sustaining a trained workforce to maintain an adequate level of qualified oversight at water treatment plants and operation of distribution systems has been identified as an important issue. This is, in part, due to the increased number of people from the large Baby Boomer generation beginning to leave the workforce. CDPH data indicate that the average age of operators certified in California is about 50, and the average age of Grade 5 treatment plant operators (the highest treatment certification available) is greater than 55 (Jordan 2006). Many water utilities will lose 30 to 50 percent of their current workforce within the next 5 to 7 years, which will result in an unprecedented knowledge drain. A knowledge retention strategy is necessary to ensure long-term success.

Knowledge retention, broadly termed succession planning, is the process of identifying and preparing suitable employees through mentoring, training, and job rotation to replace key staff, such as treatment or utility managers, within an organization as current managers retire. Succession planning will become more important in the near future to ensure the transfer of knowledge as less experienced staff moves into higher decision-making positions. This issue applies to both the public and private water sector, as well as to the government agencies that regulate the water industry. Graduating engineering students show a noticeable lack of interest in the water industry.

In November 2006, CDPH introduced the Expense Reimbursement Grant Program (ERG) for small water system operators using a U.S. EPA grant. ERG provided funding for small water system operators to receive reimbursement for training to become certified operators or to maintain and advance their operator certification levels. This program provided training reimbursement for operators until all funding was expended in early 2011.

Treatment Technologies for Small Water Systems

Providing safe and affordable drinking water is still a significant challenge for small water systems. Economies of scale typically become more limited for the small system size categories, resulting in per-household costs for compliance with new regulations that can be more than four times higher than those for medium-to-large water systems (U.S. EPA 2006). There have been advances in the effective use of point-of-use (POU) and point-of-entry (POE) technologies for certain contaminants under controlled circumstances for some small drinking water systems (Cadmus Group 2006). POU devices are those that treat water at the location where it is consumed, such as at the tap or a drinking fountain. POE devices are those that treat all of the water entering a home or building, not just water that is consumed. POE technologies treat all water that a consumer comes in contact with, such as bathing and handwashing, while a POU device provides treated water at one tap intended for drinking and cooking and is usually installed in the kitchen. The California SDWA allows the consideration and approval of POE for compliance with drinking water standards where it can be demonstrated that centralized treatment at the wellhead or surface water intake is not economically feasible. The California SDWA also allows the consideration of POU devices as per the above and provided they also demonstrate that the use of POE devices is either not economically feasible or POE devices would not be as protective of public health as POU devices. Specifically, only systems serving less than 200 connections may be eligible to use POU or POE devices and they must first demonstrate: 1) that the installation of centralized treatment is not immediately economically feasible, 2) that usage of the POE or POU device is allowed under the Federal Safe Drinking Water Act for the specific contaminant, and 3) that the water system has submitted a pre-application for funding to correct the violation for the contaminant that the POE or POU device is proposed to treat.

New treatment technologies that are cost-effective and do not require extensive operator attention are often needed to address chemical contaminants that affect small water systems. Proposition 50 provided funding to demonstrate some of these technologies. As new technologies are proposed to treat water to drinking water standards, CDPH must review and approve these technologies and use staff dedicated to reviewing these technical aspects of drinking water treatment.

Treatment Residuals Disposal

In many areas, treatment options for contaminants are limited due to residual disposal issues. For example, the disposal of brine from ion exchange and reverse osmosis treatment has been identified as a potential source of salinity in groundwater. California, and especially the central San Joaquin Valley, is experiencing increased salts in the groundwater. As the salinity of local groundwater sources increase, more water customers use water softeners to improve the quality at their tap. This, in turn, results in a higher discharge of salts to the wastewater treatment plants which increases the salinity of wastewater and exacerbates the problem. The Central Valley Regional Water Quality Control Board completed a study in May 2006 on salinity in groundwater in the Central Valley which introduced the concept of a long-term salinity management program for the Central Valley and for California (Central Valley Regional Water Quality Control Board 2006). Additional information is available in Chapter 19, Salt and Salinity Management.

Disposal of residuals, such as backwash water or spent media, poses additional costs for water treatment, especially those that may be classified as a hazardous or radioactive waste due to the concentration and leaching characteristics of the contaminant. Selection of treatment alternatives, especially for arsenic, must consider disposal issues. The spent treatment plant media must be evaluated under the California Waste Extraction Test (WET) for classification prior to determining appropriate disposal options due to the potential for the arsenic to leach from the media in a landfill environment. The California WET classification is more stringent than federal leaching tests. The City of Glendale water system conducted a study that evaluated treatment alternatives for removal of chromium-6 that included disposal of treatment residuals. See Box 15-2 for additional information.

PLACEHOLDER Box 15-2 City of Glendale Chromium-6 Treatment Residuals Disposal Study

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Security of Drinking Water Facilities

Water system facilities are vulnerable to security breaches, acts of terrorism, and natural disasters (all-hazards). Both water system personnel and the general public have developed a greater awareness of the vulnerability of California's critical infrastructure and key resources because of the events of September 11, 2001, Hurricane Katrina in 2005, and many other disasters and incidents since then. The enhancement of security and emergency response and recovery capabilities are crucial to maintain a reliable and adequate supply and delivery of safe, clean, and wholesome drinking water. Just as crucial are forming, developing, and exercising relationships with partners and stakeholders.

Under the U.S. Public Health Security and Bioterrorism Preparedness and Response Act of 2002, drinking water utilities serving more than 3,300 people were required to conduct Vulnerability Assessments and develop/update their Emergency Response Plans to address these vulnerabilities. All of California's water utilities in this category have prepared these documents. These documents and their implementation are an important element in building and maintaining the ability to respond to security breaches and other catastrophes and to recover from them.

The accomplishments by the water industry, the wastewater industry, and regulatory agencies to protect California's water and wastewater facilities from all-hazards include:

- Emergency Water Quality Sample Kit (EWQSK) developed by CDPH and based on the U.S. EPA Response Protocol Toolbox. These sample kits provide water systems with a resource to sample drinking water quickly for an unknown contaminant during a credible event.
- Partnerships between water agencies and the regulatory community were established to address emergency response and recovery, including the California Water/Wastewater Agency Response Network (CalWARN), Laboratory Response Network (LRN), and the California Mutual Aid Laboratory Network (CAMAL Net). WARN systems facilitate a utilities-helping-utilities approach by providing assistance during a crisis. By establishing mutual aid agreements before a crisis occurs, WARN participants pave the way for member utilities within and outside of their respective regions to send valuable aid in a quick and efficient manner. WARN participants can access specialized resources to assess and assist water and wastewater systems until such time as the system can develop a permanent operating solution.
- Water Infrastructure Security Enhancement (WISE) Guidelines, drafted for the Physical Security of Water/Wastewater Utilities by national water and wastewater organizations, provide recommendations for the management, operation, construction, and retrofit of water and wastewater treatment plants and distribution/collection systems to enhance physical security. The WISE Guidelines are at http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Security.aspx.
- Coordination among partners and stakeholders and developing those relationships are critical to a successful response and recovery, and to improving situational and operational awareness. The water and wastewater communities and respective regulatory organizations

have formed many groups to accomplish this critical network that meet periodically and communicate regularly. These groups include:
  - InfraGard that was created and sponsored by the Federal Bureau of Investigation as a public/private information sharing and analysis collaborative. It was established since the majority of critical infrastructures and key resources are owned and operated by private entities.
  - Local Terrorism Early Warning Groups (TEWG) that meet to exchange information and discuss local and national issues.
  - Water ISAC, a Department of Homeland Security- recognized center, that provides water and wastewater information sharing and analysis.
- Recognizing that communication during a crisis can make or break a successful response, the CDPH used the Centers for Disease Control and Prevention Crisis and Emergency Risk Communication (CERC) Toolkit and modified it specifically for the water and wastewater community. CDPH has conducted numerous CERC training classes detailing the toolkit and espousing the virtues of being prepared to address risk communication during a crisis.
- A successful response and recovery is also strongly dependent upon exercising the policies, procedures, processes, and partnerships. To that goal, the regulatory communities are providing training to the water and wastewater communities on designing and conducting tabletop exercises. Tabletop exercises are a low cost, low stress process by which partners can work together on scenarios and discover any gaps or gains. This is further strengthened by the nationwide acceptance, training, and use of the Department of Homeland Security, Homeland Security Exercise and Evaluation Program (HSEEP) which provides a nationwide framework for exercises and improvement.
- Numerous tools have been created to help water and wastewater utilities be better prepared for crises and emergencies. These include:
  - Water Health and Economic Analysis Tool (WHEAT), that is a consequence analysis tool designed to assist drinking water and wastewater utility owners and operators in quantifying human health and economic consequences for a variety of scenarios that pose a significant risk to the water sector.
  - Vulnerability Self-Assessment Tool (VSAT), that is a risk assessment software tool for water, wastewater, and combined utilities to assist drinking water and wastewater owners and operators to conduct security threats and natural hazards risk assessment as well as updating utility Emergency Response Plans.
  - FedFUNDS, that is a new interactive Web site created to help water and wastewater utilities navigate through the maze of Federal Disaster Funding. See http://water.epa.gov/infrastructure/watersecurity/funding/fedfunds/index.cfm.

Existing and Emerging Contaminants

New contaminants in drinking water are often discovered and then regulated because of increased pollution, improved analytical abilities, and/or a better understanding of health effects. Media attention to a particular contaminant has also resulted in a legislative response to address or speed up the regulatory process. Examples include hexavalent chromium, pharmaceuticals, and personal care products. In addition, the health effects of many known contaminants are re-evaluated and re-regulated as new information becomes available. For many emerging contaminants, such as pharmaceuticals and personal care products, there may not yet be a full understanding of the health risks they cause in drinking water and available treatment technologies to remove them from drinking water. For such contaminants, the pollution prevention and matching water quality to water use resource management strategies will help address water quality concerns while additional information is gathered. For pharmaceuticals and personal care products control of discharge to the environment is the best initial approach, via source control programs and reduction through wastewater treatment, rather than relying on drinking water treatment.

Emerging contaminants may be created by treatment itself, for instance, when water utilities implement new methods or processes for disinfecting water that may create new disinfection byproducts. For some contaminants, treatment options may be available, but they may be relatively expensive.

Recommendations

Because of the importance of drinking water, there is strong interest from many groups to promote improvements to drinking water treatment and distribution facilities, operation, and management. These groups include:

- Water system managers and operators.
- Local governmental agencies—city, county, planning.
- Regulatory agencies such as CDPH, local primacy agencies (county-level), and the U.S. EPA.
- Environmental and community stakeholders.

Based on the major issues outlined in this chapter, the following additional actions are needed to ensure there is adequate protection of public health through the maintenance of infrastructure, advancements in water treatment, and developing and maintaining relationships among the groups that advocate safe drinking water:

1. The Legislature should take necessary steps to maintain a sustainable source of funding of water supply, water treatment, and infrastructure projects to ensure a safe and reliable supply of drinking water for individuals and communities and to provide state matching funds for federal Safe Drinking Water State Revolving Fund monies.
2. Additional funding should be provided to CDPH to provide increased technical assistance to small water systems related to asset management and rate setting.
3. The Legislature should take steps to require publicly owned water systems to establish water rate structures at a level necessary to provide safe water, replace critical infrastructure, and repay financing for treatment and distribution system improvements necessary to meet drinking water standards.
4. State government should support enactment of a federal water infrastructure trust fund act that would provide a reliable source of federal assistance to construct and repair water treatment plants.
5. Additional programs should be developed to encourage regionalization and consolidation of public water systems. Regionalization and consolidation are useful both in achieving compliance with water quality standards and in providing an adequate economy of scale for operating and maintaining existing facilities as well as planning for future needs.
6. State government should continue to develop funding for small water systems and disadvantaged communities to assist in complying with drinking water standards.
7. State government should continue to encourage conservation and develop additional incentives, such as expanded rebate programs, to allow water systems to reduce the waste of limited water resources.

8. Public water systems that provide flat rate water service should strongly consider changing to a metered water rate structure to discourage waste. In addition, water systems that have water meters for some customers but not on all service connections should strongly consider providing water meters for all customers.
9. State government should consider providing incentives that would encourage water systems to adopt rate structures that encourage conservation and discourage the waste of water.
10. The Legislature should establish a requirement for all public water systems, whether in urban or other areas of the state, to install a meter on each service connection and charge a metered rate for actual volume of water used.
11. California's regulatory agencies, such as the State Water Resources Control Board and California Department of Public Health, should maintain internship programs for college students to continue the interest of the next generation in water and environmental regulatory agencies.
12. State government should support research and development of new and innovative treatment technologies by providing funding for demonstration pilot projects. Additional program funding is also needed by CDPH to address the review and acceptance of these new treatment technologies adequately .
13. Water systems should fully evaluate residual disposal issues when planning new water treatment facilities due to increased costs and other issues associated with disposing treatment residual wastes.
14. All public water systems should be encouraged to join the California Water/Wastewater Agency Response Network. This program will provide mutual aid and assistance more quickly than the normal resource requests submitted through the Standardized Emergency Management System.
15. The control of pharmaceuticals and personal care products in the environment should be addressed initially via source control programs and reduction through wastewater treatment.

Drinking Water Treatment and Distribution in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions aren't consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn't discussed in the rest of Update 2013), there is no need for this section to appear.]

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Table 15-1 Public Water Systems in California by Class

Public Water System Classification	Number
Community	2,973
Nontransient noncommunity	1,490
Transient noncommunity	3,111
Total number of public water systems	7,574

Source: California Dept. of Public Health records, August 2012. Does not include water systems serving Native American Tribes or on tribal lands.

Table 15-2 Number and Type of CPUC-Regulated Water Agencies

CPUC class	Number of Connections Served	Number of Agencies in Class
A	>10,000	10 [a]
B	2,000-10,000	6 [a]
C	500-2,000	22
D	<500	85

Source: California Public Utilities Commission web site, June 2012.

[a] Many of the private agencies included in the number shown operate multiple water systems throughout California

Table 15-3 Treatment Plants on California Public Water System Sources

Type of Contaminant	Approximate Number of Major Treatment Plants
Surface water [a]	699
Nitrate	150 [b]
Arsenic	79 [b]
Perchlorate	40
Radiological	10 [b]
Volatile and synthetic organic chemicals	220 [b]
Aesthetic water quality	350

Source: These estimates are based on a survey of California Dept. of Public Health offices and from California Dept. of Public Health records.

[a] Surface water, defined under the California Surface Water Treatment Rule (Cal. Code Regs., tit. 22, § 64651.83.) means "all water open to the atmosphere and subject to surface runoff..." and hence would include all lakes, rivers, streams, and other water bodies. Surface water includes all groundwater sources that are deemed to be under the influence of surface water (i.e., springs, shallow wells, wells close to rivers), which must comply with the same level of treatment as surface water.

[b] Includes only chemical removal treatment facilities. Blending facilities are not included.

Table 15-4 Metropolitan Water District of Southern California Treated Water Rate History

Year	Cost of Treated Water ($/af)	
Historical and Current Water Rates		
1994	412	
1995-1996	426	
1997-2002	431	
	Tier 1 [a]	**Tier 2 [b]**
2003	408	489
2004	418	499
2005	443	524
2006	453	549
2007	478	574
2008	508	606
2009	579	695
2010	701	811
2011	744	869
2012	794	920
Projected Future Water Rates		
2013	847	997
2014	890	1032

Source: Metropolitan Water District of Southern California 2012.

[a] Tier 1 supply rate – recovers the cost of maintaining a reliable amount of supply.

[b] Tier 2 supply rate – set at Metropolitan Water District cost of developing additional supply and to encourage efficient use of local resources.

Table 15-5 California Department of Public Health Summary of Funded and Unfunded Projects

	Funded Projects		Unfunded Projects
Funding Source	Number of Systems	Funded Amount (million $)	Unfunded Need (million $)
SDWSRF	224	1,351	[a] 11,700
ARRA	51	150	
Proposition 50	78	295	366
Proposition 84	88	81	174
TOTAL	441	1,877	12,240

Source: California Department of Public Health 2012.

[a] ARRA used the SDWSRF project priority list for funding.

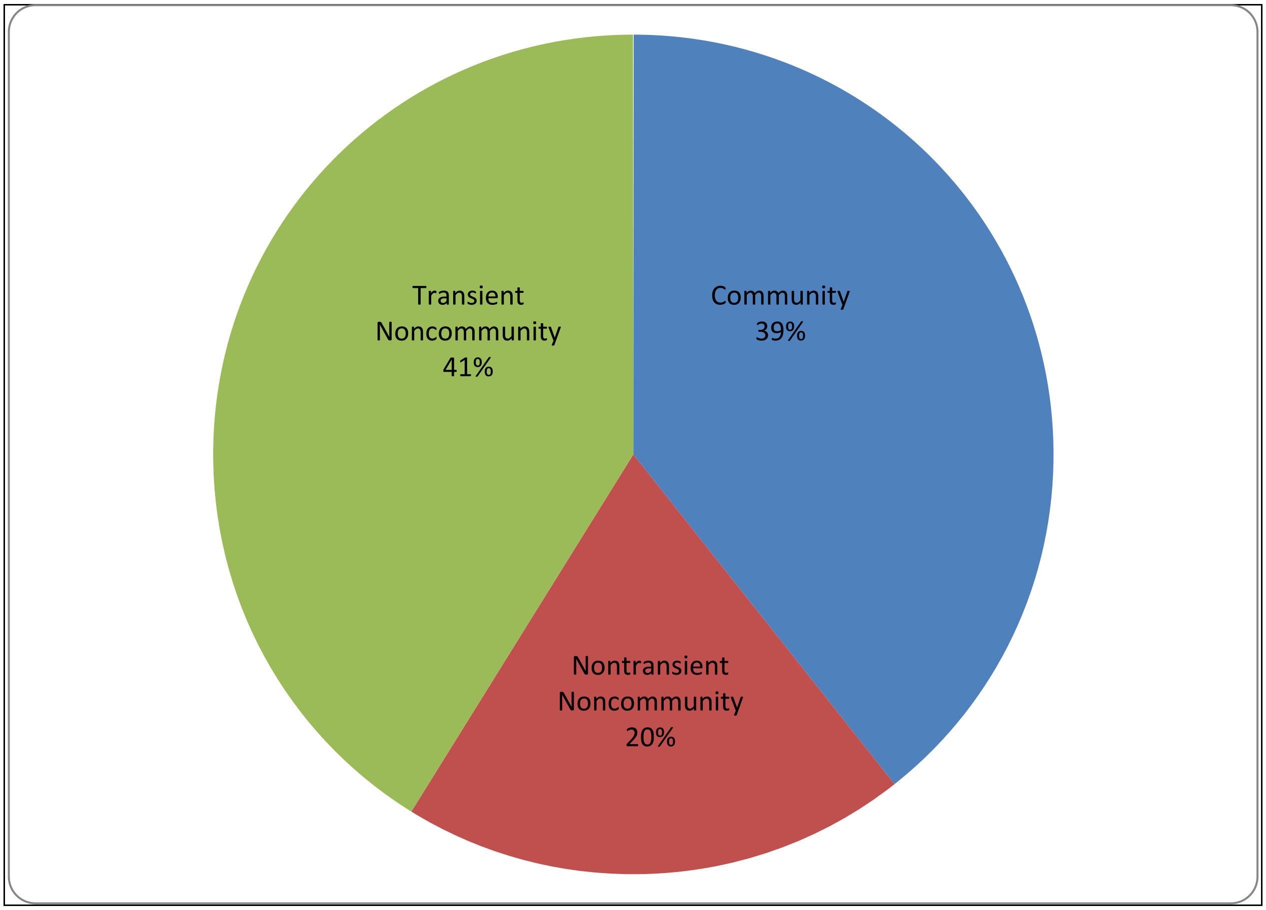
Table 15-6 California Safe Drinking Water State Revolving Fund: Capitalization Grants from the U.S. EPA

Fiscal Year	DWSRF Grant (million $)	% of National DWSRF Funds
1997	75.68	—
1998	77.11	10.83% (FY1998-2001)
1999	80.82	—
2000	83.99	—
2001	84.34	—
2002	82.46	10.24% (FY2002-2005)
2003	81.97	—
2004	85.03	—
2005	84.85	—
2006	67.10	8.15% (FY2006-2009)
2007	67.10	—
2008	66.4	—
2009 SDWSRF	66.4	8.15%
2009 ARRA [a]	159.0	8.15%
2010	137.32	9.35% (FY2010-2013)

Source: U.S. EPA Drinking Water Needs Survey 2009 and the Federal Register. See link for more information on DWSRF state allotments: (http://water.epa.gov/grants_funding/dwsrf/allotments/).

[a] In 2009, California Department of Public Health also received funding under the American Recovery and Reinvestment Act (ARRA) that essentially followed Safe Drinking Water State Revolving Fund (SDWSRF) funding rules.

Figure 15-1 Public Water System Class by Percent of Systems



Box 15-1 Rosamond Community Services District Regional Consolidation Project

The Rosamond Community Services District (CSD) Regional Consolidation Project is currently in the feasibility and planning stage to solve water quality problems of nine small water systems (one high school, four mutual water companies, one apartment complex, and three mobile home parks) in the Rosamond area. Eight systems have arsenic MCL violations and one system has a uranium MCL violation. Funding for this regional consolidation project will be through a combination of SDWSRF and Proposition 84 funding.

The ultimate plan will physically consolidate eight water systems with Rosamond CSD by using a combination of pipelines, storage tanks, and booster pumps. By consolidating the small water systems with Rosamond CSD, the customers of these small systems will receive water that meets drinking water quality standards and avoid installing treatment equipment which is very expensive to operate and maintain and may be unaffordable.

One mutual water company, which is farther away from Rosamond CSD and is currently under a court-ordered receivership with Rosamond CSD being the court appointed receiver, may need to install arsenic removal treatment equipment depending upon its affordability. This project will explore managerial consolidation of this mutual water company with the Rosamond CSD, in an effort to improve the economy of scale for this project and to improve operational reliability of any treatment installed.

It is anticipated that Rosamond CSD will request construction funding for the project following completion of the feasibility and planning studies.

Box 15-2 City of Glendale Chromium-6 Treatment Residuals Disposal Study

The City of Glendale completed a study comparing the treatment residuals waste produced by two treatment processes for removing chromium-6: a weak-based anion exchange (WBA) process and a reduction/coagulation process that removes chromium-6 through filtration (RCF).

The main waste in the WBA treatment process is spent ion exchange resin. Based on results of the federal Toxicity Characterization Leaching Procedure (TCLP) and the California Waste Extraction Test (WET), the waste resin is classified as a California-regulated non-RCRA waste and requires special handling and disposal. Additional waste characterization is needed due to the detectable quantities of uranium and thorium in Glendale's source water. While these contaminants are in the source water at concentrations below the maximum contamination levels (MCL), they are removed in the treatment process and concentrated in the resin. Testing was also conducted to determine whether the waste resin would be classified as a Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) or a Low-level Radioactive Waste (LLRW). Findings indicated that waste resin would not be classified as TENORM as long as the waste resin could be taken out of service prior to reaching uranium concentrations of 0.05% by weight, where it would require even more expensive disposal and handling as a LLRW.

The wastes from the RCF process are mostly settled solids after thickening and dewatering. The solids from the RCF process are classified as California-regulated non-RCRA waste and they are not classified as either a TENORM or a LLRW since the RCF process does not remove or concentrate appreciable quantities of uranium.

The disposal of treatment waste streams in California adds a major cost component to the cost of treating drinking water. Rather than disposal at a local landfill or other approved land disposal option, spent resin or solids must receive special handling and be sent to special disposal facilities that accept hazardous and/or radioactive materials.

Chapter 27. Watershed Management — Table of Contents

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Chapter 27. Watershed Management

Watershed management is the process of creating and implementing plans, programs, projects, and activities to restore, sustain, and enhance watershed functions. These functions provide the goods, services, and values desired by the human community that are affected by conditions within a watershed. In California, the practice of community-based watershed management, which is practiced in hundreds of watersheds throughout the state, has evolved as an effective approach to natural resource management. These community-based efforts are carried out with the active support, assistance, and participation of several State agencies and programs.

Managing at a watershed level has proven to be an appropriate organizing landscape unit for the coordination and integrated management of the numerous physical, chemical, and biological processes that make up a river basin ecosystem (Box 27-1). A watershed serves well as a common reference unit for the many different policies, actions, and processes that affect the system, and it also provides a basis for greater integration and collaboration among those policies and actions.

PLACEHOLDER Box 27-1 Watershed Defined

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of the chapter.]

Watershed Management in California

A primary objective of watershed management is to increase and sustain a watershed's ability to provide for the diverse needs of the communities that depend on it, including local, regional, State, federal, and tribal stakeholders. Significant efforts to better manage natural resources using a watershed approach are occurring in several hundred structured efforts in all regions of California, involving organizations, local governments, landowners/users, and stewardship groups along with State and federal agencies.

Many of these efforts are working to blend community goals and interests with the broader goals of the State as a whole in a manner consistent with improving environmental, social, institutional, and economic conditions within the watershed. The need to address environmental justice and social equity has been recognized and addressed, along with more traditional project management approaches.

In many communities, these organized efforts serve as forums to bring about collaborative management involving the public and private sector; the academic community; and people working at the local, regional, State, and national levels, all benefitting from the inherent capabilities of each group. The benefits of watershed-based management are being realized in such diverse locations as the upper Feather River, the Los Angeles River basin, and the Napa River.

In addition to these local efforts, a number of regional, statewide, and national initiatives have been carried out to help improve the overall ability to practice watershed management. A chronology of some notable initiatives in California can be found in *California Water Plan Update 2009*, Volume 2, Chapter 27, available online at http://www.waterplan.water.ca.gov/cwpu2009/index.cfm (California Department of Water Resources 2009).

Bond measures have brought significant funding for the maintenance and restoration work that is needed in many of California's watersheds. Proposition 50 (2002) and Proposition 84 (2006) stressed the need for integrated planning that includes objectives at the watershed and regional scales, and provide incentives to carry out work consistent with these plans.

Potential Benefits

Managing people's interactions with and impacts on natural ecosystems using a watershed approach that emphasizes maintaining, restoring, or enhancing the many functions associated with these natural systems produces a number of significant benefits. Many of the benefits (such as reliable quantities of clean water, agricultural or forest products, and biofuels) or avoided costs (such as reduced flood or fire damages) can be described using traditional economic terms, such as products, goods, or services, and are readily quantified and valued in the traditional marketplace. Other values associated with natural systems such as biological diversity, disease suppression, and climate moderation are more difficult to quantify monetarily because these values are not routinely traded in the marketplace. As a result, the term "ecosystem services" is often used to better describe and equate the monetary and non-monetary values or benefits provided to society by healthy watersheds. Some typical watershed products, goods, and services are listed in Table 27-1.

PLACEHOLDER Table 27-1 Typical List of Watershed Products, Goods, and Services

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Potential Costs

Costs associated with watershed management depend on many factors, such as the size of the watershed; the land and water use activities occurring in the watershed; the condition and trends of the watershed; and the values, goods, and services demanded from the watershed. Much of the cost of watershed management in California is associated with the specific land or water use activities occurring within the watershed on a recurring basis and is directly related to these uses. The additional or external costs of watershed management that are discussed in this chapter tend to be associated with interventions designed to influence management or improve the results of management, to offer specific protection for certain functions and values, or to restore the functional conditions and associated uses of a watershed. These interventions may come from various levels of government or interests either within or outside the watershed. A methodological approach is used for estimating costs associated with specific watershed-scale resource management efforts. Using this approach, the potential costs associated with these interventions are estimated by:

- Extrapolating costs based on available estimates of other program expenditures (see Table 27-2, used in *California Water Plan Update 2005* and *California Water Plan Update 2009*, in resource management strategy chapters on watershed management). Estimates are based on CALFED watershed management estimates scaled up for statewide coverage.
- Applying a "willingness to pay" approach based on existing examples (using CALFED Watershed Program analysis as part of program finance plan development).

In addition to the more easily quantified benefits of well-functioning watersheds, effective watershed management can also result in significant avoided costs, such as lessened fire and flood damage, erosion and sediment loss reduction, water quality maintenance, reduced illnesses and treatment costs, and control of agricultural pests. An example is shown in Box 27-2, "Watershed Degradation and Water Treatment Costs."

PLACEHOLDER Table 27-2 Estimates of Watershed Management Costs to Year 2030

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

PLACEHOLDER Box 27-2 Watershed Degradation and Water Treatment Costs

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Willingness to Pay

To estimate the approximate external costs to fully implement the watershed management strategy, an analysis developed by the CALFED Watershed Program was used, which examined areas where communities have chosen to provide quantifiable financial support for watershed management, thus demonstrating "a willingness to pay" for the services provided by a well-managed watershed. This analysis, developed using methods described by the U.S. Department of Energy (Ulibarri and Wellman 1997) and the U.S. Congressional Research Service (Breedlove 1999), is an attempt to assign a monetary value to effective watershed management.

Napa County was used as a basis for this comparison for several reasons. First, it has a demographic similarity to the demographic makeup of the state as a whole. Second, taxes are collected that are directly tied to implementation of community-generated watershed management plans; these tax levies also demonstrate strong local support among voters and elected officials for the values inherent in improved watershed management. Finally, these funds are generated and dispersed locally, by locally responsive government entities.

Valuations from three different Napa County tax measures were investigated:

- A half-cent sales tax passed by 68 percent of voters in the late 1990s that generates approximately $10 million in revenue per year specifically for watershed management (the "Living River" program).
- A parcel tax of $12.70 per parcel that is supported and levied within the city of Napa for watershed management.
- An additional parcel tax of $12 per year specifically for stormwater runoff management inside the city's watersheds.

These assessments generate funds (based on 2009 estimates) that range from nearly $14,000 per square mile for the sales tax revenue, to just less than $1,600 per square mile for the parcel tax. For the purposes of this value estimate, a lower amount of $1,572 per square mile is used, which in turn is adjusted to account for the slight difference in demographic statistics between Napa and California at large. These value estimates (Table 27-3) represent the annual, external cost of fully implementing the watershed management strategy over approximately half the surface area of California, including all or part of the Sacramento River, San Joaquin River, Tulare Lake, San Francisco Bay, South Coast, and South Lahontan hydrologic regions.

PLACEHOLDER Table 27-3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Simple extrapolation of this value to the entire land area of the state would result in an estimated annual cost of $221 million to fully implement the strategy. For this example, “fully implement” suggests extensive application within the regions of the policy-level and strategic practice recommendations in this chapter. It should be noted here that an as-yet-undetermined, but likely significant, portion of that cost is not an added cost, but existing expenditures applied differently. For instance, permits and stream alteration agreements issued by watershed boundary instead of jurisdictional boundary could result in considerable added benefit and positive effect without adding to the real cost of implementation. Also, land use planning done on the basis of watershed impact may yield higher beneficial results without increasing costs.

Major Implementation Issues

Managing land and water resources for selected products, services, and values has altered the conditions and functions of many watersheds in California. These management activities have produced some negative effects that need to be addressed to continue to effectively manage and utilize watershed services.

Altered Hydrologic Cycles

The hydrologic cycle includes precipitation, flow of water over the land and under ground, and evaporation into the atmosphere. How land is managed can reduce rainwater infiltration and the timing and volume of runoff. Storms are increasingly characterized by high-intensity runoff over short periods, especially in urban areas but also in some rural areas, which creates a risk of flooding and reduces the ability of the water supply infrastructure to capture water for use during dry times. This compression of runoffs robs the streams and landscape of groundwater, leading to dry land, a shift in vegetation types, lower and warmer streams, and deterioration of stream channels, all of which lead to shifts in the plants and wildlife that can be supported. In some areas, diversion of water from streams in the watershed to other regions outside the watershed, or application of water imported from outside the watershed, has dramatically changed ecological functions or altered the flow of water through the watershed.

Altered Nutrient Cycles

As watersheds are developed, the amount of dissolved nutrients in streams within the watershed is increased, often from fertilizers or biosolids. These increased concentrations of nutrients can trigger dramatic changes in water bodies, vegetation, and wildlife communities. Nutrients generated by human activity are frequently exported from the location where they are generated or applied by humans to a downstream or downslope water body, often from inappropriate use or excessive application rates, where they can support algae or other plant growth that impairs the usability and ecological quality of water bodies. In addition to direct effects on surface waters and groundwater, increased nutrients can lead to the establishment of non-native invasive plant species at the expense of native vegetation. Many native plants evolved under relatively low nutrient conditions, and increased nutrient availability often creates conditions that favor non-native invasive plant species, which can outcompete the native vegetation and form stands of a single species with little or no biological diversity, little habitat value for wildlife, and altered soil conditions such as reduced infiltration capacity.

Life Cycles and Migration Patterns of Wildlife

Many projects built in the past, prior to modern environmental laws such as the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA), have disrupted wildlife migration corridors or destroyed or degraded habitat that is critical for certain animal life stages. Some examples of the effects of watershed alteration on wildlife ecology are found in the changes in freshwater inflows to coastal wetlands caused by changed watershed conditions, which directly affect many estuarine and ocean species that breed and rear in these communities; blocked access to spawning and rearing habitats for anadromous fish by the dams that impound water on most significant California waterways; and reduction in extent of the riparian forests that support migration of Pacific Flyway bird species.

Fire and Water

Active suppression of wildland fires since the 1920s has created an increased risk of larger, more intense wildfires that do much more damage to watersheds than fires of historical intensities. Modern watersheds have limited capabilities of rapidly recovering from these fires, and accelerated soil erosion, diminished productivity and diversity of plant communities, displaced wildlife, significant alterations of natural biological cycles, and limited subsequent human use of the lands are typical aftereffects. Catastrophic fires also have large effects on hydrology and water quality within a watershed, causing increased surface runoff and reduced infiltration, creating more frequent and severe downstream flood events, exacerbating water quality problems, increasing operation and maintenance costs for reservoirs and canal systems, and producing large economic losses to local communities.

Climate Change

Watershed integrity is vulnerable to the changes in temperature, precipitation, and water flows that are likely under currently projected scenarios of climate change. As indicated in Box 27-1, each element of a watershed system must be considered in context with the others because changes in one element (e.g., the hydrologic cycle) spur changes in the others (e.g., the roles of flood and fire), creating a different system outcome. Watersheds within regions where precipitation decreases can become more susceptible to pests, fires, and pollutants. Projected increases in storm intensity could increase inland and coastal flooding, increasing the likelihood of downstream property damage and loss of life, and runoff from high-intensity storms would cause increased rates of soil erosion and soil loss, particularly in watersheds recovering from recent droughts and fires, because soils in those areas will lack vegetation cover that stabilizes soils.

Adaptation

As indicated in Table 27-1, a diverse watershed ecosystem can be resilient to changes in climate, so maintaining healthy watershed ecosystems will be of critical importance in the face of a changing climate by ensuring that ecosystem functions within a watershed will continue to provide the goods, services, and values of the systems we rely on today. How land is managed affects the way watersheds can adapt to the effects of climate change, and an effective watershed management strategy provides multiple benefits to human society, such as producing water, food, fiber, and fuel; mitigating floods and droughts; providing aquatic and terrestrial habitats and recreational opportunities; moderating local climates; and maintaining biodiversity and healthy soils. Managing interactions with natural watershed systems to maintain, restore, and enhance the many functions within a watershed allows Californians to have reliable quantities of clean water, as well as agricultural and forest products. An effective watershed management strategy also helps to reduce the cost of flood and fire damages, suppress disease, and increase biodiversity.

Mitigation

California's forested watershed ecosystems have relatively high carbon sequestration potential, and appropriate vegetation management can significantly increase rates of carbon sequestration as well as reduce rates of natural greenhouse gas (GHG) emissions. Improved watershed management for water reuse, pollution control, and other ecosystem services could provide multiple opportunities to reduce the energy use and emissions of GHGs. Tracking and reporting changes in California's major watersheds could help to assess and evaluate water quality and watershed conditions for controlling pollution and saving related energy.

Supporting adaptive management programs could provide opportunities to control energy use and GHG emissions by avoiding negative impacts on ecological conditions, water quality, and watershed functions; and adjusting the operations or redesigning existing projects to create benefits for climate change mitigation. Providing technical information and watershed education and outreach in the decision-making process could have long-term benefits for climate change mitigation related to the maintenance and improvement of watershed functions, water conservation, water reuse, and water pollution prevention.

Other opportunities within this strategy to mitigate for energy use and GHG emissions include management actions to maintain and improve watershed function, such as: designing and selecting projects to avoid negative impacts on ecological conditions, water quality, and watershed functions; and controlling stormwater, reducing surface runoff, and retaining intact floodplains and wetlands to maintain and improve watershed function and control water pollution.

Water use efficiency practices in watersheds could have benefits for reducing energy use and GHG emissions. These include decreasing the amount of irrigated landscaping in the watershed and increasing the use of native vegetation in landscaping and agricultural buffer lands; and installing and maintaining stream flow gauges to measure water use. Improving watershed ecosystem functions by restoring and preserving stream channel morphology and creating habitats around stream and river corridors could provide carbon sequestration potential for GHG reduction. However, energy use efficiency and clean energy standards should be used to offset related GHG emissions during restoration.

Links to other Resource Management Strategies

Watershed management is linked to the following resource management strategy chapters within this volume:

- Chapter 4, "Flood Management."
- Chapter 15, "Drinking Water Treatment and Distribution."
- Chapter 18, "Pollution Prevention."
- Chapter 19, "Salt and Salinity Management."
- Chapter 20, "Urban Stormwater Runoff Management."
- Chapter 21, "Agricultural Land Stewardship."
- Chapter 22, "Ecosystem Restoration."
- Chapter 23, "Forest Management."

- Chapter 24, “Land Use Planning and Management.”
- Chapter 25, “Recharge Area Protection
- Chapter 29, “Outreach and Engagement.”

PLACEHOLDER Box 27-3 High Sierra Snow Fence Application: an Innovative Tool for Watershed Management

[Any draft tables, figures, and boxes that accompany this text for the public review draft are included at the end of this chapter.]

Recommendations

Policy-Level Recommendations

1. Establish a scientifically valid means of tracking and reporting changes in the state’s major watersheds that provide reliable, current information to local communities, State and federal agencies, and others, regarding the net effects of management against the background of external change.
2. Support adaptive management programs that regularly assess the performance and condition of projects and programs to determine if they are satisfying ecological and community needs compatibly. Adjust the operations or redesign existing projects or programs as needed.
3. Clearly define expected products, goods, and services at the State level, to provide a large-scale basis from which to apply local variations and additions.
4. As appropriate and feasible, coordinate State funding and support within watersheds and between programs to generate more focused, measurable results.
5. More effectively align agency goals and methods to reflect coordinated approaches to resource management using watersheds as the unit of implementation and effectiveness measurement.
6. Provide easy access to technical information such as geographic information system layers, monitoring data, planning models and templates, and assessment techniques from multiple sources, which are useful at multiple levels of decision-making.
7. Conduct management activities in a manner, and within a context, that is consistent with watershed dynamics and characteristics.
8. Provide local land-use decision-makers with watershed education and information access to promote maintenance and improvement of watershed functions in local decision-making.

Strategic Practice Recommendations

1. Use a watershed approach to coordinate forest management, land use, agricultural land stewardship, integrated resources planning, and other appropriate resource strategies and actions.
2. Design and select projects with ecological processes in mind and with a goal of making the projects as representative of the local ecology as possible.
3. Increase precipitation infiltration into the soil to reduce surface runoff to a level that is typical of natural runoff retention patterns. This goal is often achieved by reducing impervious surfaces within a watershed. Retain intact floodplain and other wetlands to the extent possible, to maintain or increase residence time of water in the watershed.
4. Decrease the amount of irrigated landscaping in the watershed and increase the use of native vegetation in landscaping and agricultural buffer lands.

5. Design appropriate wildlife migration corridors and biological diversity support patches within watersheds when planning fire-safe vegetation alteration.
6. Promote the installation and maintenance of stream flow gauges in major drainages.
7. Maintain and create habitat around stream and river corridors that is compatible with stream and river functions. Provide as much upslope compatibility with these corridors as possible.
8. Design drainage and stormwater runoff controls to maximize infiltration into local aquifers, and minimize immediate downstream discharges during runoff.
9. Provide regionally appropriate, regular, and dependable educational materials to encourage water conservation, water reuse, and water pollution prevention.
10. Restore and preserve stream channel morphology to provide floodwaters access to the floodplain and to encourage stable banks and channel form.
11. Restore the characteristics and functions of native grasslands, woodlands, forests, and other wildlands.
12. Remove or control invasive weeds as a part of overall resource management efforts.
13. Protect soil resources and restore the functions of drastically disturbed soils, to slow runoff and increase rainfall infiltration.
14. Proactively address the recovery of special-status species, at both watershed and population scales, and incorporate measures to avoid future listing of other at-risk species.

Watershed Management in the Water Plan

[This is a new heading for Update 2013. If necessary, this section will discuss the ways the resource management strategy is treated in this chapter, in the regional reports and in the sustainability indicators. If the three mentions aren’t consistent, the reason for the conflict will be discussed (i.e., the regional reports are emphasizing a different aspect of the strategy). If the three mentions are consistent with each other (or if the strategy isn’t discussed in the rest of Update 2013), there is no need for this section to appear.]

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Table 27-1 Typical List of Watershed Products, Goods and Services

Typical watershed products, goods and services (also described as ecosystem services)	Benefit of service
Provision of water supplies	Agriculture, municipal, industrial, and other beneficial uses
Provision of food, fiber, fuel	Sustainable production of agricultural and forest products that are dependent on healthy productive soils, favorable climate and water conditions, and the availability of pollinators
Water purification/waste treatment	Well managed watersheds produce clean, cool water generally useful for a broad range of beneficial uses. Virtually all fresh water used in California originates as precipitation that is intercepted, captured, routed, and released from watersheds in California and the Colorado River Basin.
Flood mitigation	Healthy watersheds with adequate distributed wetlands and functional floodplains moderate the volume and timing of surface runoff reducing flood damage.
Drought mitigation/flow attenuation	A healthy watershed works like a sponge to store and release water to both streams and groundwater. In California, healthy watersheds increase the residence time of water, and tend to store and release water longer into the dry season.
Provision of aquatic and terrestrial habitat	Uplands, rivers, streams, floodplains, and wetlands provide necessary habitats for fish, birds, mammals, and countless other species, and generally sustain a strong level of biological diversity that provides wide benefits to society.
Soil fertility, health, productivity	Soil health and fertility is an essential component of primary ecosystem production, and is critical for maintenance of important terrestrial, floodplain, riparian, and wetland components and processes.
Nutrient, mineral cycling and delivery, carbon sequestration	Cycling of nutrients is necessary to maintain healthy, diverse biological systems, to sustain biological diversity that mediates disease, and to sustain populations of native species.
Biodiversity maintenance	Diverse assemblages of species work to provide the services (including all those listed in this table) upon which societies depend. Conserving genetic diversity preserves options for the future and increases the resilience of ecosystems in the face of the impacts of a changing climate.
Recreational opportunities	Swimming, fishing, hunting, boating, wildlife viewing, hiking, and skiing are all delivered or enhanced in healthy watersheds, often resulting in concurrent economic improvements in local communities reliant on recreation as a source of economic sustenance or growth.
Climate moderation/buffering	Generally, a diversified watershed ecological system is more robust and resilient to rapid climate changes or other types of disturbance. Maintaining a resilient watershed ecosystem will be of critical importance in the face of a changing climate. That adaptation will better ensure that watershed ecosystem functions will continue to provide the goods, services, and values of the systems we experience today.
Aesthetics	Quality of life is a major, but difficult to quantify, benefit of watershed conditions. Pleasant surroundings, with clean air, clean water, and adequate recreational opportunities have been shown to be beneficial across a broad spectrum of social structures.
Managing salinity gradients	Freshwater flow regimes can determine salinity gradients in deltas, coastal estuaries and near-shore marine environments, a key to biological richness and complexity.

Source: Table content adapted from *Rivers for Life: Managing Water for People and Nature* (2003) by Sandra Postel and Brian Richter.

Table 27-2 Estimates of Watershed Management Costs to Year 2030, from Water Plan Update 2005 and CALFED Program Estimates

Period (years)	Assessment-planning [a] ($ millions)	Public process [b] ($ millions)	Projects [c] ($ millions)	Total for period ($ millions)
2004-2009	$10-$37.5	$8-$16	$14-$80	$160-$667
2010-2015	$10-$30	$8-$16	$14-$88	$160-$804
2016-2030	$10-$25	$8-$16	$14-$100	$160-$2,115
Total				**$480-$3,586**

Source: *California Water Plan Update 2005,* Volume 2 Resource Management Strategies, Chapter 25, Watershed Management.

Note: The CALFED service area is defined as the Sacramento and San Joaquin River basins, the Tulare Lake Basin, The Delta and San Francisco Bay Area, and that portion of central and Southern California serviced by the State Water Project

[a] CALFED service area estimated as 40% of statewide need. Therefore, statewide assessment and planning = 2.5 x CALFED values from draft CALFED Finance Plan (2004)

[b] The service area for public process estimated as 25% of the statewide need. Therefore, statewide public process = 4x CALFED values

[c] For projects, CALFED service area is estimated to be 25% of the statewide need. Therefore, statewide projects = 4x CALFED values

Table 27-3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay

Napa County	Less 10%	Bay-Delta watershed area (mi^2)	Southern California area (mi^2)	Total value estimated
$1,572 per mi^2	$1,414 per mi^2	48,050		$67,942,700
			30,000	$42,420,000
Total Valuation:				**$110,362,700**

Source: California Department of Water Resources 2011

Box 27-1 Watershed Defined

What is a Watershed?

In its historical definition, a watershed is the divide between two drainage streams or rivers separating rainfall runoff into one or the other of the basins. In recent years, the term has been applied to mean the entirety of each of the basins, instead of just the divide between them. The Continental Divide is a watershed according to the earlier definition, where rainfall runoff is directed toward the Gulf of Mexico or toward the Pacific Ocean. The Mississippi River basin and the Colorado River basin are watersheds under the new definition. Other parts of the world use the terms catchment, or river basin, to describe the drainage area between (historical) watersheds. It is from the earlier definition of watershed that we derive the phrase “watershed event”—an occurrence that changes the pattern of all that follows, moving the flow of events toward a different outcome.

A watershed includes all natural and artificial (manmade) features, including its surface and subsurface features: climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. A watershed may be a small area or as large as the Sacramento, San Joaquin or Klamath River basins.

Using watersheds as organizing units for planning and implementation of natural resource management means that:

- Large regions can be divided along topographic lines that describe a natural system more accurately than typical jurisdictional lines.
- Condition and trends analysis can be done on the basis of the entire natural system, in concert with economic and social conditions.
- Communities, including resource management and regulatory agencies, within and outside a particular watershed can better track and understand the cumulative impacts of management activities on the watershed system.
- Managers within each watershed can more effectively adjust their measures and policies to meet management goals across scales, including regional and statewide goals.
- Multi-objective planning is facilitated by inclusion in, and reference to, a whole-system context.

Effective management recognizes the mutually dependent interaction of various basic elements of a watershed system including the hydrologic cycle, nutrient and carbon cycling, energy flows and transfer, soil and geologic characteristics, plant and animal ecology and the role of flood, fire and other large scale disturbance.

Each must be considered in context with the others, because change in one spurs changes in the others, creating a different system outcome.

Box 27-2 Watershed Degradation and Water Treatment Costs

The development of watershed and aquifer recharge lands results in increased contamination of drinking water. With increased contamination come increased treatment costs. The costs can be prevented with a greater emphasis on source protection. A study of 27 water suppliers conducted by the Trust for Public Land and the American Water Works Association in 2002 found that the more forest cover in a watershed, the lower the treatment costs. According to the study, "Approximately 50 to 55 percent of the variation in treatment costs can be explained by the percent of forest cover in the source area. For every 10 percent increase in forest cover in the source area, treatment and chemical costs decreased approximately 20 percent, up to about 60 percent forest cover."

The study did not gather enough data on suppliers with over 65 percent forest cover to draw conclusions; however, it is suspected that treatment costs level out when forest cover is between 70 and 100 percent. The 50 percent variation in treatment costs that cannot be explained by the percent forest cover in the watershed is likely explained by varying treatment practices, the size of the facility (larger facilities realize economies of scale), the location and intensity of development and row crops in the watershed, and agricultural, urban, and forestry management practices. The table shows the change in treatment costs predicted by this analysis, and the average daily and annual cost of treatment if a supplier treats 22 million gallons per day.

Table A Change in Water Treatment Costs for Each 10% of Forest Cover in Source Watershed

Percent of watershed forested	Treatment and chemical costs per million gallons	Change in costs	Average treatment costs	
			Daily	Per year
10%	$115	19%	$2,530	$923,450
20%	$93	20%	$2,046	$746,790
30%	$73	21%	$1,606	$586,190
40%	$58	21%	$1,276	$465,740
50%	$46	21%	$1,012	$369,380
60%	$37	19%	$814	$297,110

Source: Extracted from Land Conservation and the Future of America's Drinking Water - Protecting the Source (2004). Published by the Trust for Public Lands and the American Water Works Association

Box 27-3 High Sierra Snow Fence Application: an Innovative Tool for Watershed Management

Overview

In coming years, mountain stream runoff is expected to result in higher flows over shorter durations, thereby causing earlier and greater spring flooding followed by a longer, dry summer period, which may affect sensitive environments. Snow fences have been used extensively by state transportation departments to reduce snow drifting over roadways. Local-scale strategic placement of properly designed snow fencing could also be used as an effective tool for water management to reduce the negative effects of warming, strengthen forest and watershed management, and facilitate slower snow melt to extend runoff into the summer. For example, the Sierra Nevada produces more than 50 percent of California's water, and snow fences could be used in some locations to accumulate larger volumes of snow mass and extend water delivery for supply and power generation. This may reduce water loss due to evaporation and sublimation, increase soil moisture retention, and enhance forest wildlife habitat. Details of a proposed pilot study on snow fences, application in neighboring states, preliminary cost estimates, and a work plan outline and schedule appear in *Catch the Drift: An Innovative Application of Snow Fencing Technology* (California Department of Water Resources 2012).

Snow Fence Concepts

To improve watershed management, snow fencing should be strategically placed in small openings (clear cuts or high elevation meadows) less than one-half hectare. Key positioning atop ridgelines adjacent to cliffs and ravines could also enhance snow mass accumulation. As shown below, when positioned perpendicular to the prevailing wind direction, snow fencing intercepts the wind to reduce snowflake velocity and create a snow sedimentation basin downwind of the fence.

PLACEHOLDER Figure A Snow Transport and Deposition Mechanism

[The draft figure follows the text of this box.]

PLACEHOLDER Photo A Living Snow Fence Depicted in Summer and Winter

[The draft photo follows the text of this box.]

Effective snow fences are 6-12 feet high. Snow mass collected behind the fence is distributed over a longitudinal area that can be up to 25 times the fence height. Manmade snow fences can be placed parallel to planted rows of trees that serve as a natural, living fence. After the trees mature, the manmade fence can be removed.

Benefits — Water Management

Snow fences can:

- Reduce spring runoff and extend snowmelt.
- Augment water supply.
- Support better local flood control.
- Help extend hydroelectric generation into summer.

Benefits — Social Impacts

Snow fences can:

- Strengthen public relations by suggesting realistic, simple, and economic solutions that could be implemented at the local level.
- Benefit tribal lands.
- Increase interagency water management collaboration.

Benefits — Environment and Habitat

Snow fences can:

- Accelerate ecosystem restoration.
- Improve habitat by decreasing sedimentation and erosion and increasing reforestation, meadow improvement, and forest sustainability.
- Enhance soil moisture retention.
- Augment streams with colder water in summer to benefit aquatic life by increasing dissolved oxygen levels.

Potential Challenges

Potential challenges to using snow fences as a tool:

- Unknown benefit-to-cost ratio in California.
- Permitting requirements.
- Sponsors and funding.
- Operations and maintenance.

Figure A Snow Transport and Deposition Mechanism

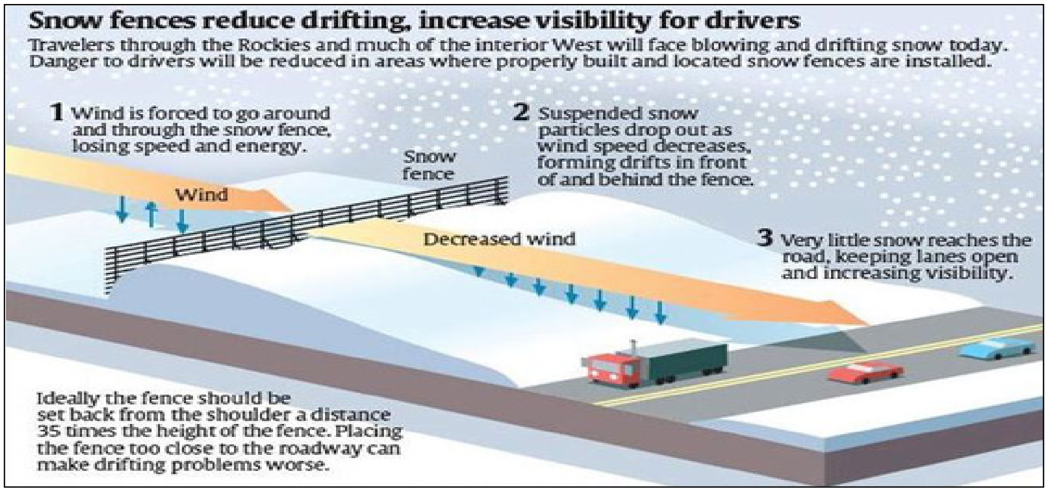

Photo A Living Snow Fence Depicted in Summer and Winter

[photo to come]